TerraSIRch SIR System-3000

User's Manual

We Provide Complete Survey Solutions
Information People Can Use
Since 1970

13 Klein Drive, PO Box 97
North Salem, NH 03073-0097
Phone: (603) 893-1109 / Fax: (603) 889-3984
www.geophysical.com
Sales@geophysical.com

Published by Geophysical Survey Systems, Inc.
13 Klein Drive
North Salem, New Hampshire 03073-0097

Printed in the United States

<u>Limited Warranty, Limitations Of Liability And Restrictions</u>

Geophysical Survey Systems, Inc. hereinafter referred to as GSSI, warrants that, for a period of 12 months from the delivery date to the original purchaser, GSSI's products will be free from defects in materials and workmanship. EXCEPT FOR THE FOREGOING LIMITED WARRANTY, GSSI DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. GSSI's obligation is limited to repairing or replacing parts or equipment which are returned to GSSI, transportation and insurance pre-paid, without alteration or further damage, and which in GSSI's judgment, were defective or became defective during normal use.

GSSI ASSUMES NO LIABILITY FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR INJURIES CAUSED BY PROPER OR IMPROPER OPERATION OF ITS EQUIPMENT, WHETHER OR NOT DEFECTIVE.

Before returning any equipment to GSSI, a Return Material Authorization (RMA) number must be obtained. Please call the GSSI Customer Service Manager who will assign an RMA number. Be sure to have the serial number of the unit available

FCC Class B Compliance

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment or residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the introduction manual, may cause harmful interference to radio communications. However, there is not guarantee that interference will not occur in a particular installation.

Shielded cables must be used with this unit to ensure compliance with the Class B FCC limits.

Canadian Emissions Requirements

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numerique de la classe A est conforme a la norme NMB-003 du Canada.

GSSI is required to notify customers of the following restrictions.

This device complies with part 15 of the FCC Rules:

Operation is subject to the following conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, Including interference that may cause undesired operation

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Operation of this device is restricted to law enforcement, fire and rescue officials, scientific research institutes, commercial mining companies, and construction companies. Operation by any other party is a violation of 47 U.S.C. § 301 and could subject the operator to serious legal penalties.

Coordination Requirements.

(a) UWB imaging systems require coordination through the FCC before the equipment may be used. The operator shall comply with any constraints on equipment usage resulting from this coordination.

(b) The users of UWB imaging devices shall supply detailed operational areas to the FCC Office of Engineering and Technology who shall coordinate this information with the Federal Government through the National Telecommunications and Information Administration. The information provided by the UWB operator shall include the name, address and other pertinent contact information of the user, the desired geographical area of operation, and the FCC ID number and other nomenclature of the UWB device. This material shall be submitted to the following address:

Frequency Coordination Branch., OET
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
ATTN: UWB Coordination

(d) Users of authorized, coordinated UWB systems may transfer them to other qualified users and to different locations upon coordination of change of ownership or location to the FCC and coordination with existing authorized operations.

(e) The NTIA/FCC coordination report shall include any needed constraints that apply to day-to-day operations. Such constraints could specify prohibited areas of operations or areas located near authorized radio stations for which additional coordination is required before operation of the UWB equipment. If additional local coordination is required, a local coordination contact will be provided.

(f) The coordination of routine UWB operations shall not take longer than 15 business days from the receipt of the coordination request by NTIA. Special temporary operations may be handled with an expedited turn-around time when circumstances warrant. The operation of UWB systems in emergency situations involving the safety of life or property may occur without coordination provided a notification procedure, similar to that contained in CFR47 Section 2.405(a)-(e), is followed by the UWB equipment user.

Table of Contents

Part 1: Introduction

This manual is designed for both the novice and experienced user of ground penetrating radar. It is intended as both a reference and a teaching tool and it is recommended that you read the entire manual, regardless of your level of GPR experience. For information about GPR theory, please see the list of general geophysics references that can be found in Appendix F.

If you experience operation problems with your system, GSSI Tech Support can be reached 9am-5pm EST, Monday-Friday, at 1-800-524-3011, or at (603) 893-1109 (International).

1.1: Unpacking Your System.

Thank you for purchasing a GSSI TerraSIRch SIR System-3000 (hereafter referred to as SIR-3000). A packing list is included with your shipment that identifies all of the items that are in your order. You should check your shipment against the packing list upon receipt of your shipment. If you find an item is missing or was damaged during the shipment, please call or fax your sales representative immediately so that we can correct the problem.

Your SIR-3000 system contains the following items:

1- Digital Control Unit (DC-3000) with preloaded operating system.
1 - Transit Case
2 - Batteries
1- AC Adaptor
1- Operation Manual

Your choice of antenna, cables, and post-processing software is available for an additional purchase.

1.2: General Description

The SIR-3000 is a lightweight, portable, single channel ground penetrating radar system that is ideal for a wide variety of applications. The various components of the SIR-3000 are described below.

The major external features of the control unit are the keypad, color SVGA video screen, connector panel, battery slot, and indicator lights. The video screen allows you to view data in real time or in playback mode. It is readable in bright sunlight, though an optional sunshade for the unit is available. Prolonged exposure to direct sunlight will cause the screen to heat up and may affect screen visibility.

***Note*:** Do not use Windex or other ammonia-based glass cleaner to clean the display screen as this may damage the coating. Use only a clean, slightly damp cloth to gently clean the screen.

The battery slot in the front of the unit accepts the 10.8 V Lithium-Ion rechargeable battery provided. Survey time with a fully charged battery is approximately 3 hours. Batteries are recharged with the optional battery charger or by simply leaving the battery in the unit and connecting the unit to a standard AC source and leaving the system in standby mode. Time to recharge a battery is approximately 4-5 hours. Be sure to keep the battery slot cover on the unit while in use to ensure that no dust or dirt enters the unit's interior.

Hardware Connections

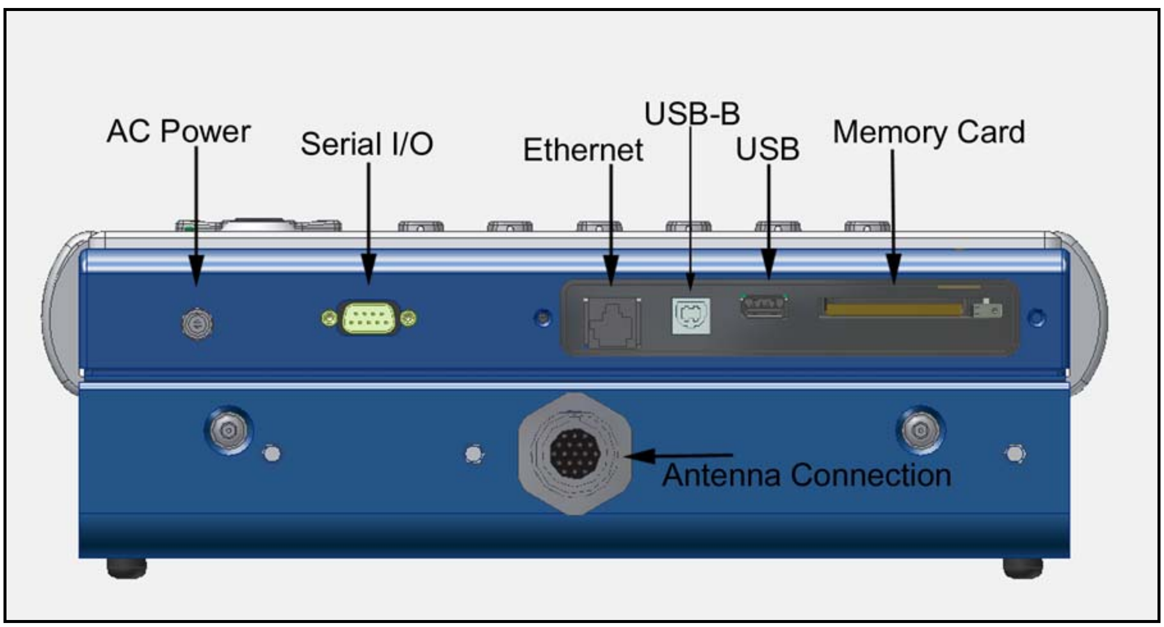
On the back edge of the unit, the SIR-3000 has six connectors and one slot for the memory card. The five top-row connectors are, from left to right: AC Power, Serial I/O (RS232), Ethernet, USB-B, and USB-A.

Memory Card: Data can be stored on Compact Flash cards, USB key drives (Compact Flash format) (RECOMMENDED), or IBM Microdrives for transfer to PC for processing. These cards are widely available and are the same type used in other digital devices such as cameras, MP3 players, and camcorders. The amount of system card memory is totally dependent on your choice of memory card size.

- Since radar profiles can sometimes be several megabytes in size, GSSI recommends that you purchase a high capacity card.
- If there is no memory card inserted, the system will save the data profile to its internal system memory and data will have to be transferred with the USB connection or by later inserting a memory card. The internal memory capacity is approximately 512 megabytes. Please see Part 4: Data Transfer and File Maintenance for additional information on transfer.

Antenna Connector: The large, protruding 19-pin connector at the back of the system is for the antenna control cable. You will notice that antenna connection on the SIR-3000 has five notches cut from the metal. These mate with the five raised nubs on the control cable to ensure that the pins line up properly.

- Screw the cable connector collar onto the SIR-3000 to make proper contact. The cable should only be *hand-tightened*. *Do not use a wrench* to tighten the connection as over-tightening will result in damage. The cable connector collar should be screwed down far enough to cover the red line on the SIR-3000 connector.



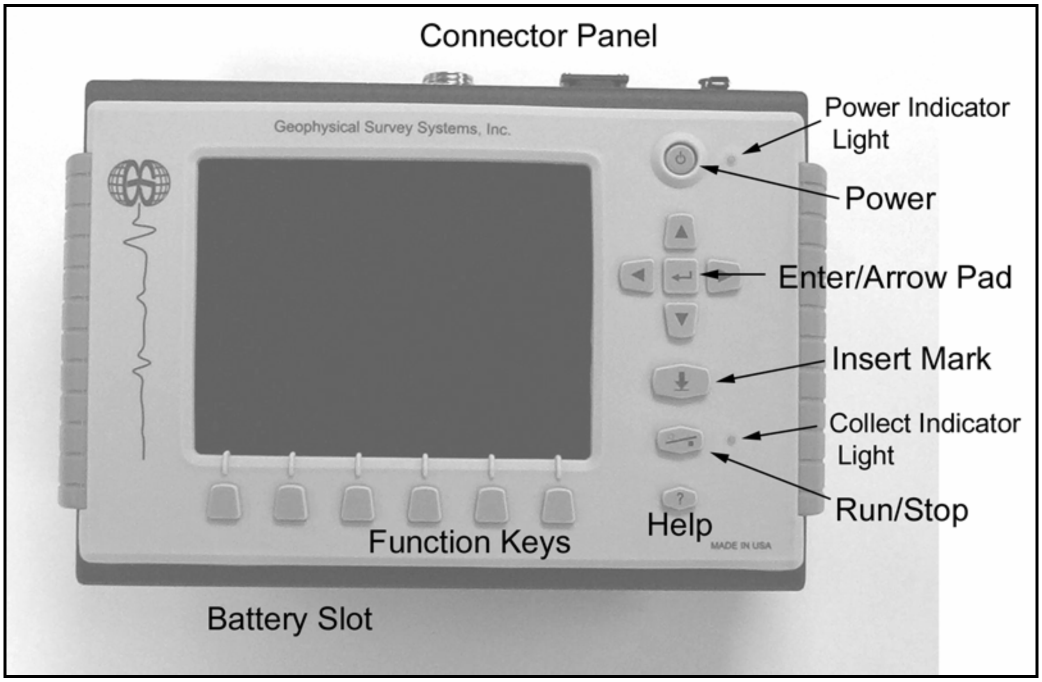
AC Power: Plug in the supplied universal AC power adaptor to run the system from 110-240 V, 47-63 Hz power.

Serial I/O: This is a standard serial connection that can be used to establish communication between the SIR-3000 and a GPS. Please see Part 6: Using a GPS with your SIR-3000 for additional information.

Ethernet: This port allows the SIR-3000 to be connected to an Ethernet network or to other devices through an Ethernet connection. This will be available in future software updates.

USB-B and USB-A: These ports are for connection to a variety of USB peripherals, including a keyboard, memory device, and a printer. Future software updates will allow you to use a printer.

Keypad



The keypad on the front of the unit has fifteen (15) buttons and two indicator lights.

Power: This button puts the system into standby. The only way to turn the system off is to remove power. The system will also turn on automatically when you connect a battery or AC power. If you are running on battery power, the Power Indicator Light will flash green when you are low on battery power. Double-clicking this button while in one of the six data collection programs will cause the system to reboot to the TerraSIRch splash screen.

Enter/Arrow Pad: This grouping of five buttons is located right below the power button. The Enter key is the one in the center. These buttons allow you to navigate through the menu tree.

- Highlighting a menu item by pushing Up or Down the menu tree and then pushing the Right arrow will open any menus that are under that menu choice. Left arrow will collapse those menu items to refresh the menu tree.

- Pushing the Enter key on some menu items will cause a pop-up menu to appear so you can toggle between two or more parameter choices.

  For example: to setup data collection mode, pushing Enter when Collect→Radar→Mode is highlighted will bring up a pop-up menu which will allow you to choose from Time (continuous data collect), Distance (survey wheel), or Point measurement. Highlight your choice and push Enter to see your choice applied, and then Right arrow to accept and cause the pop-up menu to disappear.

Insert Mark: This button is located below the Enter/Arrow Pad. Pushing this button while collecting data will cause the system to set a User mark in the data.

- User marks are helpful for noting distance traveled if you are not using a survey wheel and for noting the location of obstacles such as columns, trees, pits, etc.
- User marks will appear as long, dashed, vertical white lines through the data window.

Run/Stop: This button is located below the Insert Mark button. Pushing the Run/Stop button in Collect>Run stops data collection and brings up a set of crosshairs. Clicking this button again closes a data collection file and causes the system to ask if you want to save that file. Clicking this button during Setup in modes other than TerraSIRch or 3D will cause the system to re-initialize the gain and auto position servos. This will reset the gains to the area under the antenna and could minimize clipping.

Help: This button is located under the Start/Stop button. Pushing the Help button will bring up a menu of help topics. **The onscreen help is only accessible from the TerraSIRch splash screen.** Use the Mark button to highlight links and Enter to jump to a help topic. Pushing the Run/Stop button on the right hand side of the unit will take you back to the previously viewed screen.

Function Keys: These six (6) buttons are located below the video screen. Pushing one of these from the initial start screen will cause the SIR-3000 to operate in the desired software module.

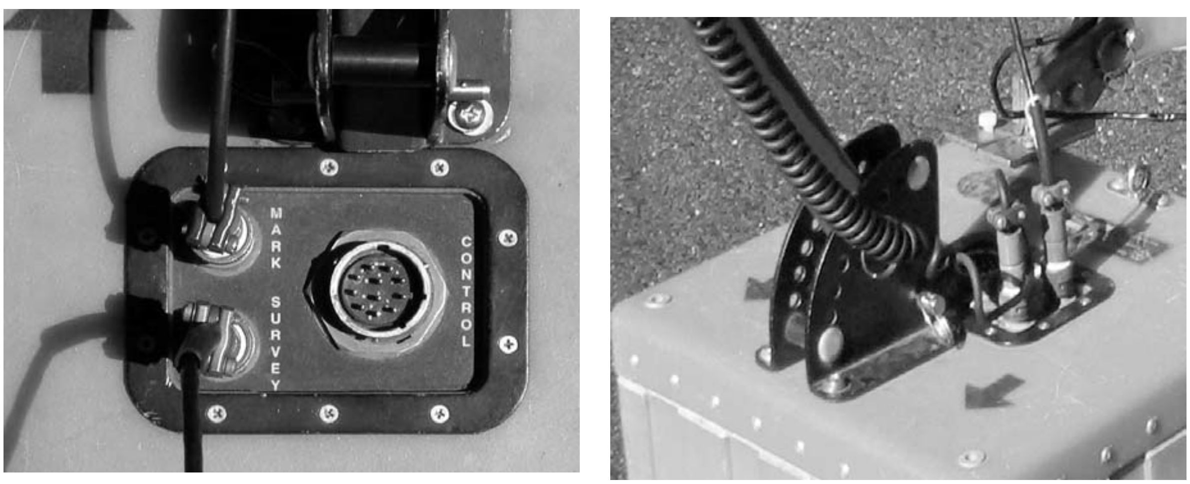
Part 2: Getting Started and TerraSIRch Module Setup

In Part 2, you will find instructions for connecting all of the hardware inputs and an introduction to the different menus and functions that are available to you in TerraSIRch mode. TerraSIRch mode allows you total control over all collection parameters and is the most versatile data collection method, usable for all GPR applications. If desired, these 2-D profiles can later be transferred to a PC for processing in GSSI's RADAN post-processing software.

2.1: Hardware Setup

Hardware setup for the SIR-3000 is very simple. We will assume the 400 MHz (Model 5103) antenna for this example, but the hardware connections are the same for other GSSI antennas, and the cable connections are clearly marked. Follow the steps below.

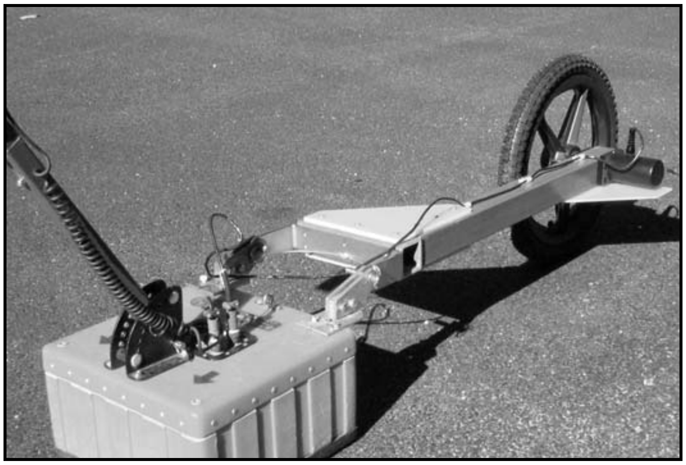
1. Attach the survey handle between the two vertical mounting plates on the top of the antenna with the two removable pins, adjust the angle for comfort, and connect the marker cable to the antenna at the Mark port.



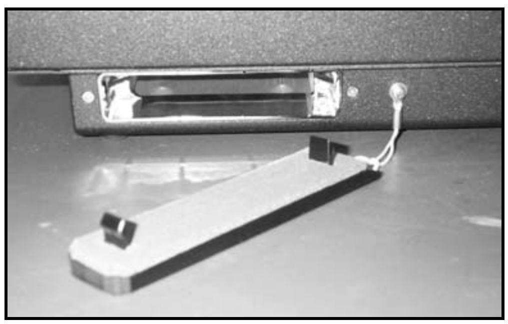
Antenna connector panel

2. Connect the female end of the antenna control cable to your antenna. Then connect the male end to the antenna connection on the back of the SIR-3000. Connect the two protective caps together.

3. Attach the survey wheel to the brackets at the back of the antenna (as shown below) and connect the cable to the Survey port on the top of the antenna. Be sure that the triangular plate protecting the survey wheel encoder faces down.



4. Connect power source (battery or AC) to the SIR-3000 and the system will turn on automatically.



If you purchased your SIR-3000 with a cart as in the UtilityScan System, or purchased the cart system separately, please see Appendix C: Mounting your SIR-3000 on a Cart. The cart also incorporates a survey wheel that is used in place of the survey wheel pictured earlier.

2.2: Boot-Up and Display Screen

After the SIR-3000 boots up, you will see the introductory screen with the words TerraSIRch, SIR-3000. There will be 6 icons positioned over the Function Keys. The first one is TerraSIRch.

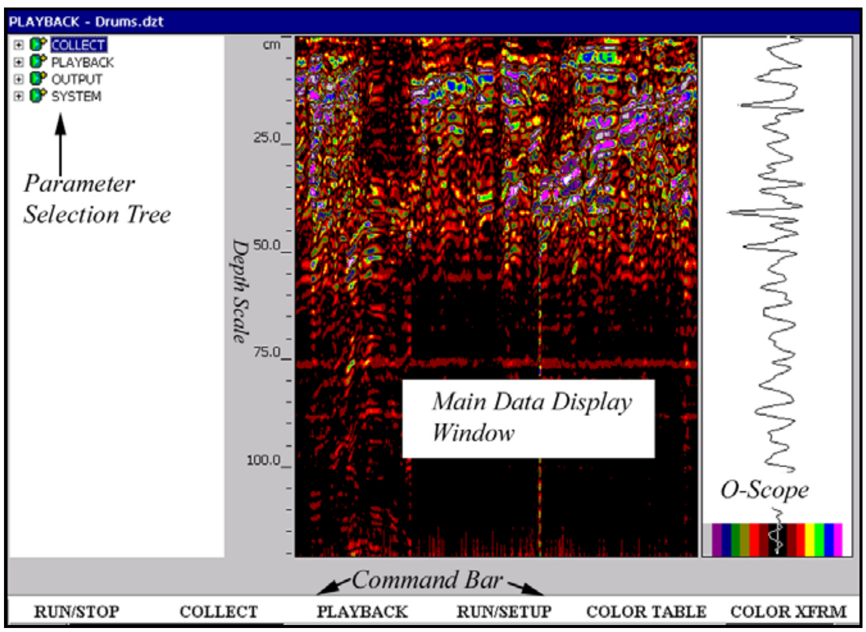
TerraSIRch mode gives you complete control over all data collection parameters. QuickStart guides are available for each of the other modes. Push the TerraSIRch button. After a moment, you will see a screen divided into three windows and there will be a bar running across the bottom with commands above each of the 6 Function Keys.

Pushing the Mark button will change your desired units from English to Metric.

After entering one of the six data collection modes, you can return to this screen by either clicking the Power button twice or by removing the power supply and reinserting it to re-boot.

Note: For information on other modes, please see Part 5.

Data Display Windows



O-Scope (right): On the far right of the screen you will see a window that shows a single radar scan in an oscilloscope-style (O-scope) depiction. This will show successive single scans as you move your antenna across an area while in Setup mode.

- Time (depth) increases down the screen.
- At the bottom of the window you will see a color bar. This shows you the distribution of colors across the range of reflection amplitudes (size of the peaks of the scan to the left and the right of center). The exact color and distribution depends on your choice of color table and color transform.

Main Display (center): The main data display window in the center shows a radar profile in linescan format. In this depiction, successive single scans are assigned color values and stacked next to each other in sequence to form a continuous image.

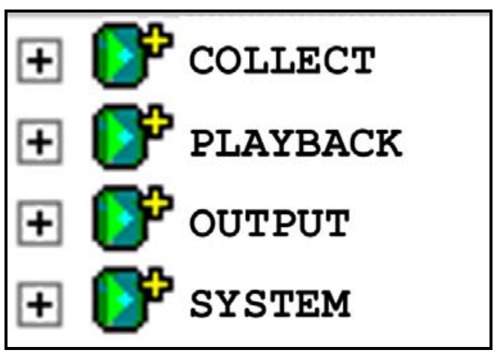
- The vertical scale on the left of this data display window shows time, depth, or sample number.
- New scans will be placed at the right side of the window and data will scroll from right to left.

Command Bar (bottom): The bar across the bottom of the screen is the Command bar and allows you different toggles and functions depending on whichever system mode you are in at the time. You can activate these commands by pushing the function key right below the wording. These commands are each explained in more detail later on when the different system modes are discussed.

Parameter Selection (left): To the left of the main data display window is the parameter selection tree window. This window is where you will navigate through the various commands, set system parameters, and enter file name information. The tree is similar to the basic folder and file browser seen in many Windows-based applications. Upon setup, you will see three choices that indicate the three modes of the SIR-3000, Collect, Playback, and Setup, as well as the System menu used to change system parameters.

2.3: System Modes and Menus: A General Description

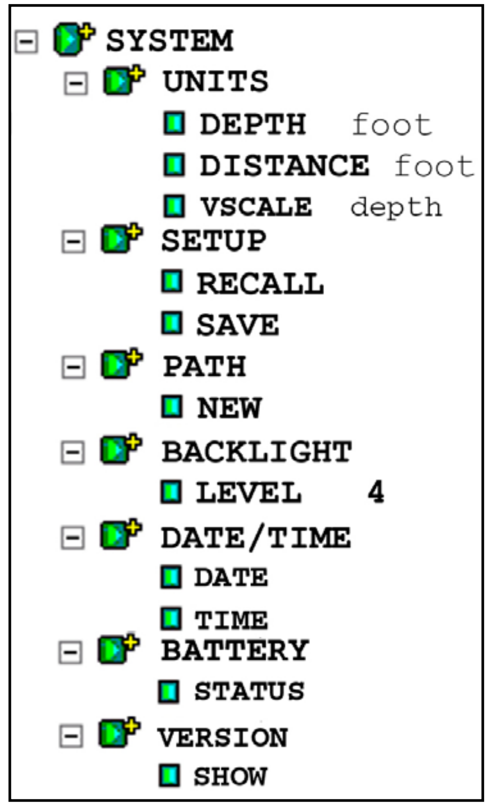
The SIR-3000 has four main system menus, Collect (page 11), Playback (page 16), Output (page 17), and System (page 9). We will first look briefly at the System menu.



The System Menu

If you are using your SIR-3000 for the first time or if you need to change some system parameters, you should enter this menu first. Highlighting System and pushing the Right arrow will bring out seven additional menu choices:

- **UNITS**
- **SETUP**
- **PATH**
- **BACKLIGHT**
- **DATE/TIME**
- **BATTERY**
- **VERSION**



Units

You can select English or Metric units for Depth and Distance, as well as the appropriate scale. For example, if you are using a very high frequency antenna to scan 18 inches into concrete, you may choose to display depth in inches and distance in feet. Under VSCALE, you can choose to display in depth or time.

Setup

This allows you to either save the current list of data collection parameters (hereafter called a setup), recall saved setup, or a factory loaded one.

- Factory setups cannot be overwritten, but the system has 16 slots where single user setups can be saved.
- After choosing your antenna under the Collect mode, you will have to find the correct setup for that antenna and recall it.
- These are named SETUP01 to SETUP16. SETUP00 is a default setup that contains the parameters the system was collecting the last time that it was used.

Path

Think of this as the location in which your files are stored on the SIR-3000. There are two basic types of paths: Common and User-defined.

- Each file in the Common path will be named with the word FILE and then a number. For example, the first data file will be FILE001, then FILE002, and so on.
- The user-defined path allows you to change the root name (instead of FILE) and the location of your data. This is useful if you are surveying multiple areas or if you prefer to name your files during collection with a site name instead of doing it later after download.
- To create a user-defined path, select New from the Path menu. This will bring up a window with six letters and an up/down arrow. Enter the new name by scrolling through the letters with the Up/Down and Right/Left arrows.

Backlight

This controls screen brightness. The scale runs from 1 to 4 with 4 being the brightest. The darker the screen is, the longer the battery will last because powering the screen is the largest draw on the power supply.

Date/Time

Use this selection to set the system's internal clock to the current date and local time. The SIR-3000 will attach this information to each radar profile you collect. This information is saved and will not be lost each time you turn the system off or remove the battery.

Battery

This selection allows you to check the remaining charge on the battery. The value here is percent of total charge remaining.

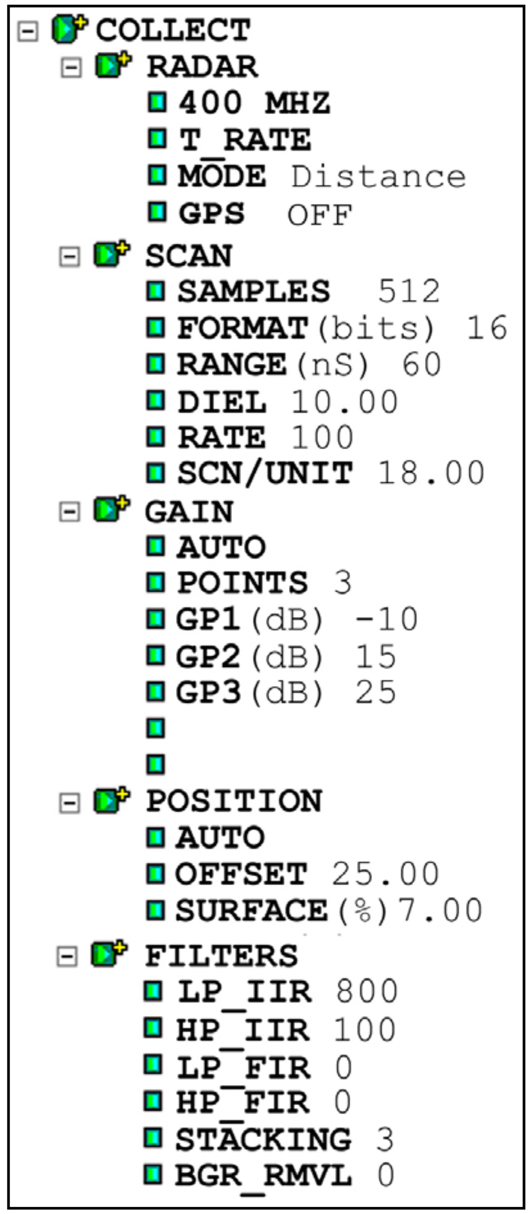
Version

This allows you to check the current version of the TerraSIRch operating software.

The Collect Menu

The Collect menu is similar to the Collect Setup mode on the older GSSI SIR-2 and SIR-2000. If you are familiar with those systems, you will notice a lot of similarities here. Under Collect, there are five main sub-menus that can each be accessed by pushing the Down arrow to highlight the sub-menu, then the Right arrow to see additional menus inside the sub-menu. These are:

- **RADAR**
- **SCAN**
- **GAIN**
- **POSITION**
- **FILTERS**



Radar

This sub-menu has four main choices: GSSI, T_RATE, MODE, and GPS.

Antenna Choice: Under this menu, you will be able to enter in the center frequency of the particular antenna you are using. This will allow the SIR-3000 to perform the auto-surface operation.

T_RATE: The T_RATE is the antenna transmit rate in KHz. This rate is capped at 100 KHz. A higher transmit rate equals faster data collection ability. Some older antennas however, are not capable of transmitting at high speeds and setting them at a high transmit rate may cause error. Please consult your antenna documentation or call GSSI Tech Support if you have any question about transmit rate. All but the oldest GSSI antennas may be driven at 100 KHz and generally, it is best to leave this at 100 KHz. If you have one of those older antennas, consult Appendix E for specific parameters

Note: If your SIR-3000 beeps repeatedly with an older/high power antenna, you may have your T_RATE set too high. This beeping is a high-voltage overload warning. A prolonged overload could damage your system. Lower your T_RATE until the beeping stops.

Mode: The Mode selection allows you to collect data as point, distance, or time based. Point data collection is commonly selected only for very deep applications or very difficult terrain. The system will record one scan every time the mark is pressed. The antenna is then moved to the next location and the next scan is taken. In time based data collection, the system is recording a certain amount of scans per second. The data density over an area depends on the speed that the antenna is moved over the ground. The rate (scans/second) is set in the Scan submenu. Distance based collection is performed with a survey wheel. The system records a certain number of scans per unit of distance. This is the most accurate data collection method and it is strongly recommended that you collect data in this mode if possible.

GPS: This selection allows you to toggle the GPS capability on and off. If you are using a GPS with your system, connect the GPS to the serial port, and toggle this to ON. Consult Part 6 of this manual for additional instructions and setting up the GPS and working with it.

Scan

Scan contains six additional menus: Samples, Format, Range, Diel, Rate, and Scn/Unit.

Samples: Each scan curve is made up of a set number of individual data points, called Samples. The more samples you collect, the smoother the scan curve and the better your vertical resolution will be.

- You can choose from a preset list of 256, 512, 1024, 2048, 4096, or 8192 samples per scan. 8192 samples should only be used in 8-bit mode.
- Note that as sample number increases, scan rate drops and file size increases.
- GSSI recommends sampling at 512 or 1024 samples per scan for most applications. More samples will be required for deep geologic or polar ice thickness applications.

Format: Data can be collected in either 8-bit or 16-bit format. 16-bit data is recommended for most applications because it has a greater dynamic range. If you are only collecting data to be viewed on the screen (no processing), or are collecting very high samples/scan data, you should set this to 8-bit data. 16-bit data profiles are much larger in terms of computer storage.

Range: Range is the time window in nanoseconds (ns) that the SIR-3000 will record reflections from a single pulse. The range has direct bearing on depth because a longer range will allow energy to penetrate deeper and give reflections from deeper down.

- It is important to remember that the range is two-way travel time, so that a range of 50 ns means that the deepest reflector is 25 ns deep.
- Bear in mind that you still have a set number of samples to draw a curve and a very long range may require a greater number of samples. The range can be set from 1-8000 ns.
- Please see Appendix B for a list of common ranges for individual antennas.

Diel: Diel refers to the dielectric constant of a material. The dielectric of a material is its ability to hold and pass a charge when an electromagnetic field is applied to it. Basically it reflects the velocity that radar energy can move through a material.

- If you know the dielectric value of the material that you are surveying through, you can enter it here and get an in-field time to depth calculation.
- Higher dielectric values mean slower travel time and shallower penetration.
- Generally speaking, water raises a material's dielectric constant, and surveys should be performed on dry material whenever possible.
- Please see Appendix D for a chart of dielectric values of common materials and a deeper discussion of dielectrics. Possible values are 1-81.

Rate: The next selection is scan Rate. This value is the number of scans the system will record in its RAM memory per second.

- If you are collecting data based on time, this is the number of scans that will be saved each second.
- If you are collecting data based on distance with a survey wheel, this number should be set very high. The reason for this is that the system is holding a set number of scans in its RAM per second, say 60.

  If you tell the system that you want to collect 60 scans a foot, and you move more than one foot per second, the system is going to look for scans which aren't available. This is called dropping a scan. Assuming your T_RATE is 100 KHz, this setting should be at 100 whenever you are collecting with a survey wheel.

  If you set this value higher than possible given the 100 KHz T_RATE and the number of samples/scan, the SIR-3000 will automatically lower it to the maximum possible.

Scn/Unit: The last choice is Scn/Unit, or scans per unit of horizontal distance. This parameter is the scan spacing when you are collecting with the survey wheel.

- Having a smaller scan spacing produces higher resolution data, but much larger file sizes. The number here is the number of scans that the system will collect per unit of distance. So for example, if you see a 12 here and the system is set to English feet, rather than Metric units, you will collect 12 scans per foot, or 1 per inch.
- Generally you want to hit your target with 5-6 scans in order to draw a recognizable hyperbola on the screen so you can tell it is a target. To set this parameter, think of how large your target is and set this so that you space 5-6 scans across it. For example, if your pipe is 6 inches wide, you should set this parameter to 12 scans/foot which equals one an inch.
- The StructureScan setting for shallow structural features in concrete is 60 scans/foot or 5 scans/inch. This is the densest recommended scan spacing, and it is only meant for the 1.5 GHz antenna.
- Lower frequency antennas, like the 400 MHz will require coarser collection (12-24 scans/foot).

Gain

Gain is the artificial addition of signal in order to counteract the natural effects of attenuation. As a radar scan travels into the ground, some of the scan is reflected, some of it is absorbed, and some of it keeps traveling down. As the scan gets deeper, it becomes weaker. We apply gain to the scan at particular points to make the subtle variations in weaker data more visible. The two choices under the gain menu are a Manual/Auto toggle and a listing of point numbers.

- Setting the Gain on manual will allow you to change the number of gain points and to add strength to the signal at your own discretion. This is not recommended for inexperienced users as it is possible to 'create' features in the data by over-gaining areas.
- Setting the gain back to Auto will cause the system to re-initialize and adjust its gains to the area under the antenna. This is useful if you find that your data is clipped (over-gained) over a particular section of your survey area. Just find the clipped area and re-servo over it to set the gains at a lower level.
- Gain is added at a number of evenly spaced points throughout the data scan. You can select up to 5 gain points, and then manually add or subtract gain values from individual points.
- Use caution not to add too much gain to a single point because you may create what will look like a layer in the data.

Position

This menu controls the position of Time-Zero. Time-Zero is the location of the beginning of the transmit pulse, and thus the beginning of the scan. Typically, having the system auto-servo itself is enough to adequately set the position. If however, you need to manually adjust the location of Time-Zero, this is the place to do it. Position contains three additional menus: Manual/Auto, Offset, and Surface.

Manual/Auto: The Manual/Auto toggle will allow you to make adjustments in manual mode and cause the system to re-servo (just like in the gain menu) when switched back to auto. GSSI recommends that inexperienced users keep the position set to Auto.

Offset: This is an internal system parameter that describes the time lag (in ns) from the SIR-3000 triggering the pulse inside of the control unit until we consider it to have transmitted from the antenna dipole. Since there is no way to accurately measure the exact moment the pulse leaves the antenna, we use the antenna's direct coupling to figure out the appropriate point to set the offset (and thus the transmit pulse). The direct coupling is the pulse that travels inside of the antenna housing, directly from the transmitter to the receiver.

As long as the antenna dipoles are not very far apart, as is the case with our larger, lower frequency antennas like the 100 MHz, the direct coupling happens before any reflections from the ground. So if we make sure that we have the direct coupling visible in the data, we can be sure that we have 100% of our data and most importantly, the ground surface to perform a depth calculation. The number here is nanoseconds from trigger pulse inside the SIR-3000. If you need to adjust this parameter, use caution not to lose that direct coupling wave.

Surface: Surface, is a useful display option and is new to the SIR-3000. This allows you to visually 'cut out' the flat part of the scan and the direct coupling, and show the scan from the first reflected target, which should be the ground surface. The other information is still collected and saved, but not displayed. This allows you to set the display to show an in-field time to depth calculation. For simplicity, the value is set as a percentage of the total vertical window. The SIR-3000 will examine the offset and the antenna type you entered under Radar to find the proper surface automatically. It will set near to the first positive peak of the direct coupling.

Filters

This menu allows you to set data collection filters to either remove interference or smooth noise. Many of these are antenna-specific, especially the High and Low Pass filters. In the ConcreteScan, StructureScan, UtilityScan, and GeologyScan, these will be automatically set when you choose your antenna under the Radar menu. **In order to set factory values for the filters you must recall a factory setup for the antenna you are using under System> Setup> Recall**. There are six menu selections here:

- LP_IIR
- HP_IIR
- LP_FIR
- HP_FIR
- STACKING
- BGR_REMOVAL

LP_IIR, HP_IIR, LP_FIR, HP_FIR: The first four are frequency filters and the values are all in MHz.

- LP stands for low-pass, which means that any frequency lower than the one entered here will be allowed to pass by and be recorded by the system.
- HP stands for high pass, and is the opposite of low-pass.
- By setting these at different ends of the antenna's bandwidth, you are determining the range of frequencies the antenna can receive.
- The default values will be adequate in almost all situations.

Stacking: After the frequency filters, the next choice is Stacking. Stacking is a noise reduction technique that operates by allowing the system to collect a set number of scans, averaging them to remove minute amounts of high frequency noise, and saving a single scan as the output.

- High frequency noise generally has a 'snowy' appearance.
- The larger the number you put in here, the smoother the data will be. It is possible to over smooth and 'smudge' out real data.
- A larger number also means that the system is performing a great deal of extra calculations and data collection speed will then be reduced.

BGR_Removal: The Background Removal filter is a horizontal high pass (remove low frequency noise) operation meant to remove flat-lying noise associated with antenna ringing.

The input number here is scans, so in order to use this filter, find the length in scans of the feature that you want to remove and put that number into the system. Features of this size or larger will be removed from the data.

- Also please note that this filter will remove your direct coupling, making positive identification of Time Zero difficult. To preserve data integrity it is best to collect data without this filter and then apply it in post-processing if needed.

The Playback Menu

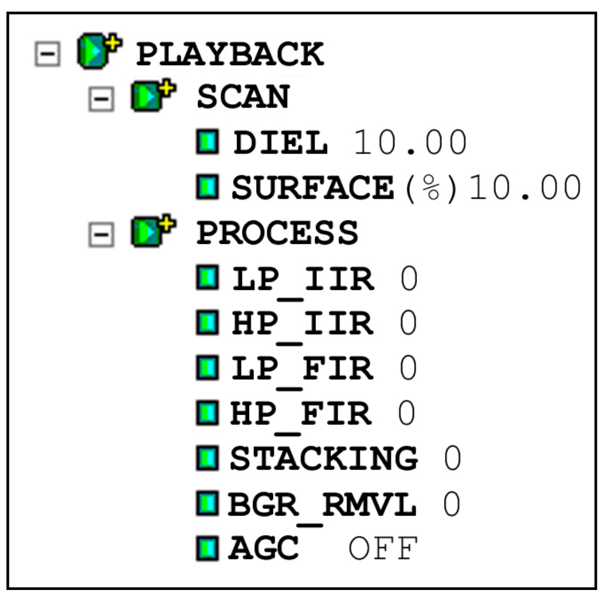
If you want to review the data you just collected or access any of the Playback functions, push the Down arrow to highlight the particular menu choice.

If you would like to review a previously collected file, pushing the Playback function key will bring up a window that lists stored data files.

If you select a single file, it will cycle through that one, or you can choose multiple files and the system will play them back in sequence.

The playback menu has two sub-menus:

- **SCAN**
- **PROCESS**



Scan

The scan sub-menu contains two parameters: Diel, and Surface.

SURFACE: Surface operates just like the surface item in the Position sub-menu of Collect menu, and it has been duplicated here for convenience. Once again, this input is percentage based. Changing the surface position here will not permanently eliminate any data.

DIEL: The Diel parameter allows you to input the dielectric constant so that the system can do a time to depth calculation. Once again, for convenience, this parameter is duplicated from the Scan sub-menu of the Collect menu. Possible values are 1-81.

Process

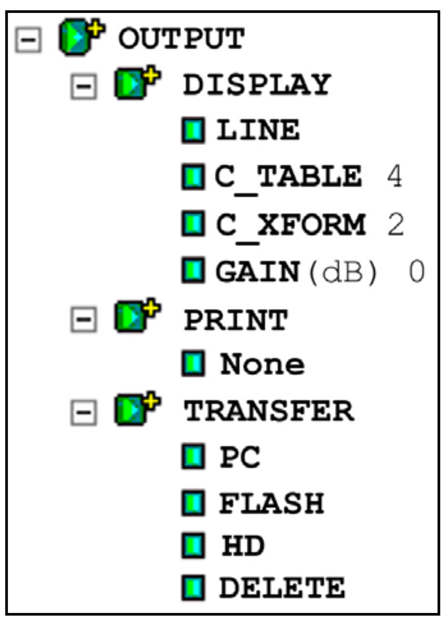
This menu allows you to apply different filters and mathematical operations to the data in order to remove noise or make subtle features more visible. These functions do not permanently alter the data, but are only for display purposes. The options here are identical to those under the Filters sub-menu in the Collect menu, but there is one additional item: AGC.

AGC: AGC stands for Automatic Gain Control. AGC lets you choose a set number of gain points (2, 3, or 5) distributed evenly through the vertical scale. The object of AGC is to normalize (make even-looking) the scan by reducing the gain for areas where the signal is very strong (usually near the surface), but adding gain with increasing attenuation (usually with depth). This dramatically slows the scroll speed of the data, especially if 5 points are used. A faster option is Display Gain, located under the Display sub-menu in Output.

The Output Menu

This menu controls the data display, printing, and file maintenance. There are three sub-menus to the Output menu:

- **DISPLAY**
- **PRINT**
- **TRANSFER**



Display

This sub-menu controls the 'look and feel' of the data displayed on the screen. Here is where you can change the mode of display, color table and distribution (transform), and add screen gain. There are four parameter inputs here: Mode(Line/Scope), C_TABLE, C_XFORM, and GAIN(dB).

Line: This is really the Mode option which allows you to toggle between Linescan and Scope display modes. Linescan is the conventional way of looking at GPR data with each scan stacked next to its neighbor and amplitude values along that scan assigned a color value. Scope, or oscilloscope, mode shows you the waveform of the individual scan.

C_TABLE: This option lets you choose which of the pre-loaded color tables to use to view your data. In addition to grayscale, there are several full color tables. It is sometimes useful to examine your data in a number of different palettes because altering the colors may help you to see different aspects of your data. There are 5 tables to choose from.

C_XFORM: Once you have the data displayed in the proper color table, you may alter the distribution of color shades across your data by changing the color transform under the C_XFORM option. This will spread out your color shades over different sections of the scan's amplitude range. You would do this to show more color shades over the extremes or the mid-range values, or just a simple black to white. Stretching more colors over a particular value ranges allows you to see more subtle variations in the data. Bear in mind that not every transform is available for every color table. There are 4 different transforms available.

Gain: The final display option is Gain. This is often referred to as display gain, because it basically just increases the amplitude of your data by multiplying every sample throughout your scan by a constant value. The result is that you will be able to better see weaker reflections, but those already strong reflections will be over-gained. This function is useful for a quick viewing of data that is attenuated or otherwise under-gained to guarantee that it was not clipped.

Print

This sub-menu will allow you to choose a pre-loaded printer so you can print data records directly from the system. In order to activate this function, select the appropriate printer from the list. To deactivate, select None. *Note:* This function will be available with future software updates.

Transfer

This sub-menu allows you to perform file maintenance. The four options for this sub-menu are: PC, FLASH, HD (hard drive), and DELETE. PC, HD, and FLASH allow you to move data from the internal system memory to an external device, such as a PC, flash card, Microdrive, or an external USB keychain drive. Transfer to a PC will be controlled by the external computer through Microsoft ActiveSync, while transfer to the removable Flash card can be done using the SIR-3000's buttons.

2.4: The Command Bar

The six keys across the bottom of the data display window have different functions depending on whether you are in Setup (3 display windows) mode or in Run (1 display window) mode.

In Setup Mode

You are in Setup mode if you can see 3 display windows with the parameter selection tree at the left. If you only see a single data screen (and no parameter selection tree), you are in Run mode.

*** You can only collect data in Run mode. ***

In ***Setup*** mode, the Command Bar will look like this:

RUN/STOP	COLLECT	PLAYBACK	RUN/SETUP	COLOR TABLE	COLOR XFRM

Setup Mode Command Bar

Run/Stop: This button stops the transmitter. The green light to the right of the Run/Stop button will turn off. If you are in Setup mode (3 display windows), this will stop data from continuously scrolling across the screen. If you are in Run mode (a single display window), this will stop the data collection and bring up crosshairs. You can then use the arrow keys to move the crosshairs over your data. You will see two sets of numbers at the bottom-right of the screen. These give the location of the crosshairs. The first number is the distance from the beginning of the profile, and the second is depth. Pushing this button again will bring up the Save File window. After selecting Yes or No, you will automatically begin collecting the next profile. The Run/Stop button under the marker button on the right hand side of the system has the same function as this key.

Collect: This button has three main functions. The first is to toggle between the Collect and Playback modes. You will know which mode you are in by looking at the top-left corner of the screen. It will say either Collect or Playback, then the File that you are on.

The second function is only in Collect Setup mode. From Collect setup (3 display windows), pushing this button will cause the transmitter to momentarily turn off, then back on. This dumps the display buffer and restarts the data scroll.

The third function is during the Collect Run mode (1 data window). Pushing this button while collecting data stops data collection, brings up the Save File dialog, then immediately opens another data file collection.

Playback: Pushing this button from the Collect Setup mode (3 display windows, Collect in the top-left corner), brings up the File Open window. This window shows stored data files that are in the current directory on the memory card. Highlight a data file with the arrow keys and push Enter to put a check in the box next to it. Click the Right arrow to enter and accept. The data will start to scroll across the screen. Make any necessary changes under the Process menu and then click Run/Setup to toggle to the Playback Run screen (1 display window). The whole data profile will scroll across the screen. When it has finished scrolling, it will stop and crosshairs will come up. This will allow you to check distance and depth of targets and to scroll back and forth through your data.

Run/Setup: This button toggles between Run mode (1 window) and Setup mode (3 windows). Pushing this while in Collect Setup begins data collection. The TerraSIRch will beep twice, then switch to Run mode. It will then beep twice again, and then it is ready to accept data. Pushing this while collecting data will cause it to beep twice again and bring up the Save File dialog. It will then go to Setup (3 windows) mode.

Pushing this while in Playback Setup will open the Playback Run mode (1 window). The data file you selected in the Open File window will scroll to the end, then stop. Crosshairs will come up. Pushing this again will take you back to the Playback Setup (3 windows).

Color Table: Pushing this key will allow you to scroll through the 5 available color tables. The TerraSIRch will redraw the data from the beginning of the display buffer in that new color. You can also change the color table under the Output > Display menu. This function is only available in Setup Mode.

Color Xform: This button allows you to scroll through the different color transforms available for some of the color tables. A color transform is a different spread of the same colors over the amplitude range of the scan. You might use a transform that has a lot of colors spread over the middle if you want to highlight variation in weak targets. Only 3 of the 5 color tables have transforms available. The red/white/blue and one of the grayscales are linear color tables and cannot be transformed. You can also change the color transform under the Output > Display menu. This function is only available in Setup Mode.

In Run Mode

You are in Run mode if you can see 1 display window. If you see 3 data display windows and the parameter selection tree), you are in Setup mode.

*** You can only collect data in Run mode. ***

In ***Run*** mode, the Command Bar will look like this:

RUN/STOP	COLLECT	PLAYBACK	RUN/SETUP	DISPLAY	DEPTH

Run Mode Command Bar

Run/Stop: Pushing this button in Collect mode will stop data collection and bring up crosshairs. Pushing this again will close the data file, bring up the Save File window, then start a new data file collection.

Pushing this in Playback mode will toggle the system from Stop to Run and the selected file will scroll across the screen to the end and bring up crosshairs. Clicking the button after the file has stopped will cause it to scroll through again.

Collect: Clicking this button in Collect Run will stop the current data and bring up the File Save dialog. After saving the file, the system will immediately begin collecting the next file. If you click this in Playback Run mode, the system will not switch to Collect Run mode and begin a new data file collection. You must enter the setup mode before switching from Playback to Collect.

Playback: Clicking this button in Playback Run will bring up the Open File dialog so that you can select another file to view. Clicking this in Collect Run will close the current collection, ask you to save the data, and open the Open File window so you can choose a file to view.

Run/Setup: Pushing this in Collect Mode will cause the Save File window to come up and close the current data file. You will then toggle to Setup Mode (3 windows). In Playback mode this key toggles between Run and Setup.

Display: Pushing this key toggles between a linescan data display and a single scan O-scope style display. The function is the same in Collect or Playback.

Depth: This button allows you to calibrate the system to a target with known depth. This will update the vertical scale and the dielectric and give you a more accurate depth calculation than simply guessing dielectric or soil type.

1. Scan over your area and find a target. Once you do, do not stop data collection, but just move the system away from that area.
2. Drill or dig down and measure the depth.
3. Back at the system, click Run/Stop to bring up crosshairs.
4. After the crosshairs come up, target then on the first positive peak of that target if it is metal, and the first negative peak if it is air. Push Depth and scroll to the correct depth. Click right to take effect.

***Note:* If you are on dirt, the dielectric value may only be an approximation.**

If you are on a homogenous material, like concrete, this calibration is good for all like material. If you are on soils, know that the dielectric of the soils can change dramatically with depth and across an area, so this is only an approximation.

Calibrating the depth in TerraSIRch mode updates the dielectric constant but keeps the fixed time range. This function in ConcreteScan, StructureScan, UtilityScan, and GeologyScan keeps the entered depth (under scan) but updates the time range required to scan to that depth given the new dielectric. After calibrating in one of these four programs (not TerraSIRch) click Run/Stop twice to reinitialize the gains.

Part 3: Setting Up Your System for Data Collection

In this part you will find instructions for configuring your SIR-3000 to collect single 2-D profiles of data that can be interpreted by themselves or stacked together in software to produce a 3-D image. You will also find instructions for setting up and collecting a 3-D project.

The first section of this part includes a step-by-step checklist to set up your system. This refers to the software setup only, not the hardware setup. If you are using a survey cart, please see Appendix C, otherwise see Section 2.1.

These first two parts also assume that you are collecting distance-based data with the survey wheel. If you are collecting data where the scan spacing is based on time (Time-based), see Part 3.3, and if you are collecting single Point data, please see Part 3.4.

Note: If the external memory card is inserted into the system before you turn it on, all data files will be *automatically* collected to that memory card. They will *not* be saved to the internal memory.

Note: Due to constraints on the internal memory, the largest single profile you can collect is 64 MB. At 512 samples/scan and 12 scans/foot, this translates to 5200 feet, or roughly one mile.

Note: You can collect up to 70 files before you need to power down the system and restart it. If you collect more than 70 without restarting the system, the SIR-3000 will hang up and you will lose that data profile that you are collecting and will need to restart the system. Remember to reload any saved setups and recheck your collection parameters to be sure that they are the same as they were before you powered down. This may also corrupt your setup file.

3.1: Setup for 2-D Collection

Step 1:

After system boot-up, press the TerraSIRch function key. After a few seconds, you will see a split screen with a wiggle trace on the right, the parameter selection tree on the left, and the main data display window in the center. If you have an antenna connected, a blue "wait" bar will scroll twice across the bottom left corner of the screen (initializing the antenna), and data will appear in the center window.

Step 2:

Examine the parameters in the Collect tree to ensure that the system is properly configured for the antenna you are using.

Load Setup: Under the System menu, open Setup and Recall a factory setup for the antenna that you are using or a saved setup that you have worked with previously.

Antenna Frequency: Under the Radar submenu, select the antenna by highlighting the proper center frequency and pushing the Right arrow. The system will re-initialize.

Check Range: With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area and find a target that you want to image. Note its position on the screen

and at what time/depth it occurs. Ideally, it should be halfway down the screen so that you can image targets above and below it. If it is not properly located, change the range under the Scan menu.

Check Scn/Unit: Make sure that you have an adequate number of scans over your target (at least 5-6) to image it properly.

Check GAIN: The thin, red line superimposed over the scan in the O-Scope window is the gain curve. The centerline of the scan is zero and to the left of it is negative (removing gain) and the right is positive (adding gain). Ensure that the scan is visible (you can see curves).

If not, select Auto under the Gain menu. This will cause the system to re-initialize and add/subtract gain to produce a visible signal. Drag the antenna over the area and look for evidence of clipping. If your data becomes clipped, leave the antenna over the area where it is occurring and re-initialize by changing Auto to Manual and then back to Auto. This will depress the gains so that the data will not clip. Remember this location if you should need to reinitialize the gains later.

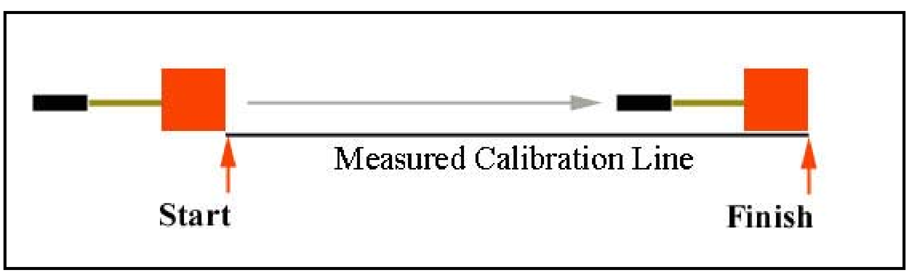
Step 3:

Survey Wheel Calibration

Make sure that Mode is set to Distance. Once you select Distance, the survey wheel calibration dialogue will come up. You can either enter the factory setting (for smooth terrain) or calibrate it to local conditions. If Distance already is shown as the selection, you should still check that the calibration is correct by selecting another choice and then selecting Distance.

In order to manually calibrate the antenna for difficult terrain, you will need to lay out a measured line on your survey surface. It can be of any length, but the longer the line, the more accurate the calibration.

Enter the calibration distance and position the antenna at the start of the calibration line. The exact part of the antenna (front, center, rear) that is positioned at the beginning of the line must finish at the end of the survey line (as pictured below). This is critical for an accurate calibration. Repeat this procedure several times and take the average result.



Default Settings for the Survey Wheel are:

Model 611 (3 5/6' wheel):	2000 ticks/meter 609.6 ticks/foot
Model 620 (16" wheel):	417 ticks/meter 127 ticks/foot
Model 623 Survey Cart:	-1583 ticks/meter -487.8 ticks/foot

Step 4:

Push the function key under Run/Setup to begin collecting a profile of data. The system will beep twice to open the Collect Run window (1 display window) and then beep again it is ready to receive data. You can also click the marker button on your antenna handle to open a data collection. At the end of your profile, push and hold down the Run/Setup key to stop data collection. The profile will be saved and can be viewed in Playback mode.

3.2: Setup for 3-D Collection

Step 1:

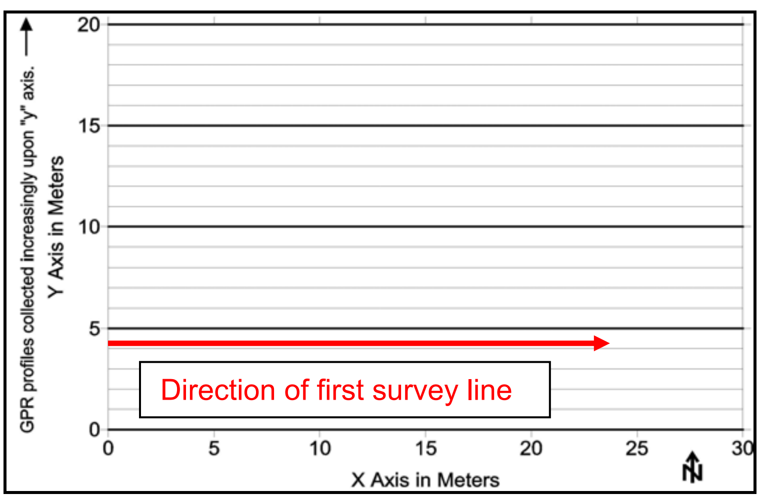
Follow all the above steps for 2D in order to set your SIR-3000 to local conditions and antenna choice.

Step 2:

You must lay out your survey grid so that you can cross your targets with at least 3 profiles. Three profiles will allow you to tell the difference between a point target and a linear target. For example, if you are looking for graves 2 meters in length, your survey profiles should be spaced 0.5 m apart, and try to orient your survey grid so that you cross the graves perpendicular to their long axis in order to have the greatest possibility of hitting them.

Step 3:

In order for your data to be properly positioned in RADAN, it must be collected in a specific direction and order. Your survey lines must run along your X axis and each new profile must be one increment higher along your Y axis (see below). This will ensure that your 3D project is correctly generated in RADAN.



Step 4:

Collect the data. Collect each survey profile as a separate file. Do not reset the gains or do anything to cause the system to re-initialize the gains. If you accidentally reset the gains, either reinitialize the system over the area that you originally set the gains on, or manually enter the gain values you have previously. Doing so will cause artificial variation in the data across an area and may obscure real data. Be sure to keep accurate notes showing the location of each file

in relation to other files and immovable objects. You will assemble the 3D project in RADAN and 3D QuickDraw after downloading the data to a PC.

3.3: Setting Up for Time-Based Data Collection

The scan spacing (horizontal resolution) of Time-based data profiles is a function of the speed that the system is collection data and the rate that the antenna is moving over the survey surface. The higher you set the Rate (in scans/second) and the slower you move the antenna, the denser the data will be.

Time-based data has no real distance tag, so the software has no idea how far you actually traveled. It is extremely important move the antenna at a constant speed and to add user marks (by clicking the mark button) at consistent intervals. Time-based data requires additional processing in RADAN to create a 3-D image. If 3-D imaging is your goal, you should collect Distance based data with a survey wheel.

Step 1:

After system boot-up, press the TerraSIRch function key. After a few seconds, you will see a split screen with a wiggle trace on the right, the parameter selection tree on the left, and the main data display window in the center. If you have an antenna connected, a blue "wait" bar will scroll twice across the bottom left corner of the screen (initializing the antenna), and data will appear in the center window.

Step 2:

Examine the parameters in the Collect tree to ensure that the system is properly configured for the antenna you are using.Antenna Frequency: **Under the Radar submenu, select the antenna by highlighting the proper center frequency and pushing the Right arrow. The system will re-initialize.**

Load Setup: Under the System menu, open Setup and Recall a factory setup for the antenna that you are using or a saved setup that you have worked with previously.

Check Range: With the system in Collect Setup mode and data scrolling across the screen, drag the antenna over the area and find a target that you want to image. Note its position on the screen and at what time/depth it occurs. Ideally, it should be halfway down the screen so that you can image targets above and below it. If it is not properly located, change the range under the Scan menu.

Check Rate: This number will be scans per second. Your data density now depends on the rate you move the antenna over the survey surface.

Check Gain: The thin, red line superimposed over the scan in the O-Scope window is the gain curve. The centerline of the scan is zero and to the left of it is negative (removing gain) and the right is positive (adding gain). Ensure that the scan is visible (you can see curves). If not, select Auto under the Gain menu. This will cause the system to re-initialize and add/subtract gain to produce a visible signal. Drag the antenna over the area and look for evidence of clipping. If your data becomes clipped, leave the antenna over the area where it is occurring and re-initialize by changing Auto to Manual and then back to Auto. This will depress the gains so that the data will not clip.

Step 3:

Push the function key under Run/Setup to begin collecting a profile of data. The system will emit a beep when it is ready to receive data. At the end of your profile, push and hold down the Run/Setup key to stop data collection. The profile will be saved and can be viewed in Playback mode.

3.4: Setting Up for Point Data Collection

Point mode collection is currently unavailable on the SIR-3000. Once available, it will be a downloadable update to the system software. Please contact your GSSI sales consultant for details.

Part 4: Data Transfer and File Maintainence

This section describes how to transfer data from the SIR-3000 to a PC for processing and interpretation, and also how to clear unwanted data from the system's memory. These functions are all accomplished under the Output menu.

Note: If the external memory card was inserted into the system before you turned it on, all data files were *automatically* collected to that memory card. They were *not* saved to the internal memory.

4.1: Transfer to a PC via USB connection.

If this is your first time transferring data via the USB connection, please see Appendix G: Installing Microsoft ActiveSync on Your PC.

Step 1: Turn on PC and SIR-3000 (If SIR-3000 has been running stop all collection and playback functions prior to continuing). Connect Master (rectangular) end of USB cable to computer. Connect Slave (square) end of USB cable to SIR-3000.

Step 2: Enter the TerraSIRch mode and click RUN/STOP to pause the system.

Step 3: Under the Output>Transfer submenu, click on PC.

Step 4: From the PC…

Wait for ActiveSync light to turn green and then right click on green ActiveSync icon located in system tray. Next click Explore; you will see the mobile device explorer. You are now accessing the SIR-3000's memory.

Step 5: Navigate to My Computer>Storage Card and go to the folder containing your projects. You will now be able to copy from one location on the storage card to the external storage card or to a folder on the PC by 'drag and drop.' When transfer is complete (wait a couple of seconds after completion) disconnect USB cable from SIR-3000.

4.2: Transfer to a PC via the External Compact Flash

Step 1: Turn on PC and SIR-3000. If the SIR-3000 has been running stop all collection and playback functions prior to continuing. Make sure that your Flash card is inserted AFTER powering up the system.

Step 2: Enter the TerraSIRch mode and click Run/Stop to pause the system.

Step 3: Under the Output>Transfer submenu, click on FLASH.

Step 4: A window will appear showing all files on the internal memory. Highlight the files and click Enter once on each file to add a 'check' next to them. Once all files are 'checked,' click the Right arrow to begin the transfer. This process will not delete the data from the internal memory.

Step 5: Remove Compact Flash card from the SIR-3000 and insert it into a USB CF card reader or similar and attach the card reader to your computer. You can now access the data as if you had another disk drive on your computer.

4.3: Transfer to a PC via an External USB Keychain/Pen Drive (HD)

This choice is available to allow you to use a USB memory 'stick' to transfer your data. This method is preferred over the other two because USB memory devices tend to be more physically durable than Flash cards. Also this method is much faster than the direct USB cable link from computer to SIR-3000.

Step 1: Turn on PC and SIR-3000. If the SIR-3000 has been running stop all collection and playback functions prior to continuing. Make sure that your memory stick is inserted AFTER powering up the system.

Step 2: Enter the TerraSIRch mode and click RUN/STOP to pause the system.

Step 3: Under the Output>Transfer submenu, click on HD.

Step 4: A window will appear showing all files on the internal memory. Highlight the files and click Enter once on each file to add a 'check' next to them. Once all files are 'checked,' click the Right arrow to begin the transfer. This process will not delete the data from the internal memory.

Step 5: Remove the USB Keychain/Pen Drive from the SIR-3000 and insert it into a USB port on your computer. You can now access the data as if you had another disk drive on your computer.

4.4: Deleting Data from the System

While it is always advisable to keep the data on your system until you have downloaded it (if desired) and checked the integrity of the data, eventually the memory may fill up or you may simply want to do some 'housecleaning.' GSSI suggests that you download all of the data from a particular jobsite and completely delete the data before starting a new job. This will help to avoid confusion over which files belong to specific projects.

Step 1: Highlight Delete under the Transfer submenu, and push Enter. You will see a window with a list of files. 3

Step 2: Using the Up and Down arrow keys, highlight the file to be deleted and push Enter to place a 'check' in the empty box to the left of the file name.

Step 3: Repeat until there are 'checks' next to all of the files you want to delete. Click the Right arrow key to accept and delete those files.

Note: When you attempt to collect a new file, the system will find the lowest number it can to assign to the new file. For example: if you have 25 files, and you delete File_001, the next file will not be File_026, it will be File_001. In other words, it will fill in any gaps in the memory before adding new files.

Part 5: Summary of Pre-Set Mode Parameters

The section briefly describes four out of the six operation modes for the SIR-3000. These modes are more limited in their customization because they are meant for specific applications or to collect data for on-screen target location as opposed to post-processing. As noted earlier, TerraSIRch mode allows you full reign over all collection parameters. The 3Dscan mode is similar to TerraSIRch in that it is fully customizable, but with the added feature of defining an easy 3D data collection project. Please note that some of these modes may require additional equipment purchase in order to get full functionality.

Expanded instructions for each of these modes are available in the form of separate QuickStart manuals. Contact your GSSI sales consultant for more details. The four additional modes are:

- **ConcreteScan**
- **StructureScan**
- **UtilityScan**
- **GeologyScan**

5.1: ConcreteScan

ConcreteScan is meant for a 'quick and dirty' scan of concrete. You would use this mode to locate shallow structural features in concrete and mark their location directly on the survey surface prior to any cutting, coring, or drilling. It works with the 1.5 GHz and 900 MHz antennas.

Upon clicking the ConcreteScan button, you will be asked to click Right for English or Left for Metric units. You will then see the data display screen and, if an antenna is connected, it will initialize and data will start to scroll across.

ConcreteScan includes the backup cursor function. This allows you to back the antenna over the line you just surveyed and get an on-screen cursor that will help you relate the location of targets in the data back to the slab. The backup line in the data is the location of the midpoint of the antenna.

What You Can Customize:

You will choose your antenna (1.5 GHz or 900 MHz) under the Radar submenu, and also select Distance or Time based collection under MODE. Remember to check the survey wheel calibration if you are using Distance.

Under the Scan submenu, choose your maximum penetration depth from a number of presets: 6, 12, 18, 36 inches, or 15, 30, 50, 100 cm.

Also set your concrete type from a number of presets ranging from Dry to Wet. This sets the dielectric constant and gives you a rough depth calculation.

What is Preset

T_RATE: 100 Samples/Scan: 512 deep, 256 shallow (12" and less)

Format/Bits: 16 RATE: 100 (deep) 200 Shallow (12" and less)

Scn/Unit: 5/inch, 2/cm Gain: 5 point Auto Filters (All)

Offset position Surface position.

5.2: StructureScan

This mode is for collecting very high-resolution 3D data over a concrete slab or wall with the 1.5 GHz antenna and GSSI's patented scan pad. This will produce a 3D cube of data that can be viewed in planview at differing depths so as to note clear locations for coring and cutting. You must use the scan pad for this mode and collect data in a prescribed fashion. Consult the StructureScan QuickStart guide for more details.

What You Can Customize:

Under the Scan submenu, choose your maximum penetration depth from a number of presets: 6, 12, or 18 inches, or 20, 30, 50 cm.

Also set your concrete type from a number of presets ranging from Dry to Wet. This sets the dielectric constant and gives you a rough depth calculation.

What is Preset

T_RATE: 100 Samples/Scan: 512 deep, 256 shallow (12" and less)

Mode: Distance Format/Bits: 16

RATE: 100 (deep), 200 shallow (12" and less) Scn/Unit: 5/inch, 2/cm

Gain: 1 point Auto Filters (All) Offset position

Surface position.

5.3: UtilityScan

UtilityScan is meant for a quick examination of an area in order to locate utilities in soils under concrete slabs or asphalt. UtilityScan can be used with the 200 MHz, 400 MHz, and 900 MHz antennas. Both the 400 MHz and the 900 MHz can be used with the survey cart. UtilityScan will allow you to create 2D profiles so that you can mark the location of utilities on pavement prior to trenching or excavation.

Upon clicking the UtilityScan button, you will be asked to click Right for English or Left for Metric units. You will then see the data display screen and, if an antenna is connected, it will initialize and data will start to scroll across.

UtilityScan includes the backup cursor function. This allows you to back the antenna over the line you just surveyed and get an on-screen cursor that will help you relate the location of targets in the data back to the slab. The backup line in the data is the location of the midpoint of the antenna.

What You Can Customize:

Choose you antenna by selecting the proper center frequency from the list under the Radar submenu. Select Distance based or Time based data collection under Mode. Remember to check the survey wheel calibration. Choose 512 (recommended) or 256 samples/scan under the SAMPLES submenu, and then choose 16 (default) or 8 bit data collection under FORMAT.

Next select your maximum depth of penetration from the list of 5 presets (3, 5, 10, 15, 20 ft) (1, 3, 5, 7 meters). Select the appropriate soil type from the list of 4 presents (Soil Type 1-4). This will set your dielectric and affect your maximum depth of penetration.

Then select your scans per unit from the list of presents. GSSI recommends a scan density of either 12 or 18 per foot, or 25 per meter.

Soil Types:

Type 1: Dielectric 4, dry sand or dry grade

Type 2: Dielectric 8, damp sand or grade, dry silt.

Type 3: Dielectric 16, agricultural fields, sandy silt, wet sand.

Type 4: Dielectric 32, wet conditions, clay.

What is Preset

T_RATE: 100	RATE: 100	Gain: 5point Auto
Filters (All)	Offset position	Surface position.

5.4: GeologyScan

This mode is optimized for 2D profiling of shallow geological features such as high bedrock, sediment bedding, water tables, etc. It is also useful for archaeological profiling. GeologyScan works with the 400 MHz, 200 MHz, and 100 MHz antennas, though only the 400 MHz is small enough to be mobilized on the survey cart. Other antennas will need to be dragged over the ground surface.

Upon clicking the GeologyScan button, you will be asked to click Right for English or Left for Metric units. You will then see the data display screen and, if an antenna is connected, it will initialize and data will start to scroll across.

There is no Quick Start Guide available for GeologyScan.

What You Can Customize:

Choose you antenna by selecting the proper center frequency from the list under the Radar submenu. Select Distance based or Time based data collection under Mode. Remember to check the survey wheel calibration. Choose 1024 (recommended), 512, or 256 samples/scan under the Samples submenu, and then choose 16 (default) or 8 bit data collection under Format.

Select the appropriate soil type from the list of 4 presents. This will set your dielectric and affect your maximum depth of penetration. Please consult the GeologyScan QuickStart guide for examples of each soil type.

Then select your scans per unit from the list of presents. The presets are 6, 12, 18 per foot for English, or 10, 25, 50 per meter for Metric units.

What is Preset

T_RATE: 100	RATE: 80	Range: Max for antenna
Gain: 5point Auto	Filters (All)	Offset position
Surface position.		

Part 6: Using a GPS with your SIR-3000

Your SIR-3000 is capable of attaching GPS coordinates to individual data profiles. This will allow you to place the beginning and the end of your survey lines into a larger, real-world coordinate system provided that you: 1) Survey in straight lines and 2). Have a GPS with sufficient accuracy for your application.

Your spatial accuracy depends on the accuracy of your GPS receiver. There are many inexpensive GPS receivers that provide 1 meter accuracy, though if your project demands finer resolution, there are systems which provide centimeter accuracy, but at a significantly higher cost. GSSI does not provide GPS systems, and has no particular manufacturer preference. The GPS you do choose must have the following:

1. Provide data output through a serial (RS232) port.
2. Output data at a baud rate of 4800.
3. Output the NMEA GGA data string.

Attaching a GPS

Step 1: Try your GPS to determine if you are getting a good position and an adequate number of satellites.

Step 2: Setup and power up your SIR-3000 as normal.

Step 3: Under Collect>Radar, highlight the GPS menu choice and click Enter. Toggle to ON and click the right arrow.

Step 4: The Enable GPS dialogue box will pop up. Follow the instructions in the window to connect your GPS.

Step 5: When you start a data profile, the SIR-3000 will capture a GPS coordinate and place it in the file header. It will do the same when you stop the data file and save it. These coordinates will be visible when you view the file header in RADAN. This function is available in RADAN starting early August, 2003.

Some other Concerns:

1. **The .TMF file**. You will notice that the SIR-3000 has created 2 files: the data profile (.DZT) and another file with the same name but a different extension (.TMF). This file will be used for some added GPS functionality which is not yet available.
2. **East vs. West**. The SIR-3000 is set to capture Latitude and Longitude coordinates rather than UTM. It does not however tag a North/South or East/West to those numbers. If you are west of the Prime Meridian, the Longitude will be negative and if you are south of the Equator, the Latitude will be negative.

Appendix A: TerraSIRch SIR-3000 System Specifications

A.1: System Hardware

Antennas: Compatible with all GSSI Antennas

Number of Channels: 1 (one)

Data Storage:

- Internal memory: 512 MB Compact Flash memory card
- Compact Flash port: Accepts industry standard Compact Flash memory or IBM Microdrive up to 2 GB (user provided)

Processor: 32-bit Intel StrongArm RISC processor, 206 MHz

Display: Enhanced 8.4" TFT, 800 × 600 resolution, 64K colors
Linescan and O-scope display modes.

Input/Output:

- Antenna input (control cable)
- DC power
- Ethernet I/O
- RS232 Serial I/O (GPS port)
- Compact Flash memory
- USB master and USB slave

Mechanical:

- Dimensions: 31.5 cm × 22 cm × 10.5 cm
  12.4" × 8.7" × 4.1"
  4.1 kg (9 lbs) including battery

Operating:

- Temperature: -10°C to 40°C
- Charging Power Requirements: 15 V DC, 4 amps
- Battery: 10.8 V DC, internal
- Transmit Rate: Up to 100 KHz

Note: The SIR-3000 will not work with the short, orange attenuated control cable that was sold with the SIR-2000. The SIR-3000 will only work with non-attenuated cables (blue or black in color).

A.2: Data Acquisition and Software

Data Format: RADAN (.dzt)

Scan Rate Examples:

- 220 scans/sec at 256 samples/scan
- 120 scans/sec at 512 samples/scan

Sample size: 8-bit or 16-bit, user-selectable

Scan Interval: User-selectable

Number of samples per scan:

256, 512, 1024, 2048, 4096, 8192

Operating Modes:

Free run, survey wheel, point collection

Time Range: 0-8000 nanoseconds full scale, user selectable

Manual or automatic gain, 1-5 points, (-20 to +80 dB)

Filters:

- Vertical: Low-Pass and High-Pass IIR and FIR
- Horizontal: Stacking, Background Removal

System Includes:

- SIR-3000 control unit
- Transit case
- AC adaptor
- User manual
- 2 batteries

Fully FCC Compliant.

Appendix B: The How-To's of Field Survey

As the old saying goes: "Garbage in, Garbage out." The biggest single factor affecting the quality of your data and your ability to make decisions based on it, is the accuracy of your data collection. This appendix has instructions and helpful hints to get you into the habit of collecting quality data from the beginning. While many of these points are only relevant to data collection over the ground, as opposed to concrete structures, you may find this section helpful no matter what your application.

B.1: Site Selection

Radar is not the proper technique for every situation. If you are unable to inspect the site, have prospective clients send a photograph of the area. As you gain experience, you will find it easy to judge an area's or an application's suitability. In the meantime, consider the four following issues before deciding whether you should conduct work at an area:

- **Topography**
- **Ground Cover**
- **Subsurface Conditions**
- **Site Accessibility**

Topography

One of the first things you should consider about a new survey area is the topography. In the first place, you need to be able to physically move the antenna over the ground surface in a fairly smooth fashion. Areas that are full of trenches or extreme slopes are not ideal. You can still survey an area of broken terrain, but it may require collecting point data rather than continuous data profiles.

Radar energy travels into the ground perpendicular to the surface. This means that if the antenna is flat on the ground, and level, you are reading right under the antenna. If, however, you are traveling up a steep slope, and the antenna is not level, you will be reading the ground slightly ahead of your current location, but it will appear on the record as being under your true location. This forward-scanning of the antenna could lead to serious position errors.

Ground Cover

If your antenna is floating on top of thick grass or a layer of gravel, you may get errors in your data because the signal is taking too long to couple (penetrate) with the ground. When this happens, more of the signal than was intended bounces off of the ground surface instead of going into the ground. Always try to keep your antenna flat on the ground surface. The systems will have no problem penetrating carpeting or low grass. A good rule of thumb for the 1500 MHz is no thicker than low carpet, and for the 400 MHz, no more than 1 inch. NEVER survey through standing water, no matter how shallow the puddle.

Subsurface Conditions

If you are working with concrete, try to make sure that the concrete has had some curing time. Three months is usually adequate for a standard slab on grade, while a suspended slab may cure faster. The best solution is to practice on slabs of different ages so that you have a first-hand feel of the way they will look. Concrete that is not well cured will be difficult to see into.

Try and find out some information about the area's soil and water content. Generally speaking, clay and water cause attenuation and impede penetration. Finding out the soil grain size (sand, silt, clay) will help you to guess the dielectric constant of the material to help you set up survey parameters and make time to depth estimations. If you have never worked with soils before, you should consult the US Department of Agriculture soils website at http://soils.usda.gov/. The site has a number of free and low cost resources including soil maps of most of the United States and guides to help you understand soils.

Site Accessibility

Simply put, can you feasibly work in the proposed area? Is the site in the middle of a dense thicket of trees, or is it the outside of a tall building, or a tight elevator shaft? Remember that GPR and geophysics depends on your ability to see contrasts in the data. The area has to be large enough for you to collect enough data to be able to make an interpretation. For example, if you need to survey an area in advance of an 18" utility trench, you want to make sure that you have some coverage over areas outside of that trench so you can see normal conditions. Always give yourself some elbow room.

B.2: Targets

The type of targets you are trying to find will govern your choice of antennas, setup parameters, or even the feasibility of radar for the application. There are two main criteria to consider:

- **Target Size**
- **Target Composition**

Target Size

All things being equal, antenna choice determines how deeply you are able to penetrate and the minimum size of the targets that you are able to see. Lower frequency antennas see deep, but the minimum target size that they can see is larger. Rather than focus on what each antenna can see, the table below lists the appropriate antenna by application and depth range.

Frequency	Sample Applications	Typical Max Depth Feet (meters)	Typical Range (ns)
1.5 GHz	Structural Concrete, Roadways, Bridge Decks	1.5 (0.5)	10-15
900 MHz	Concrete, Shallow Soils, Archaeology	3 (1)	10-20
400 MHz	Shallow Geology, Utility, Environmental, Archaeology	12 (4)	20-100
200 MHz	Geology, Environmental	25 (8)	70-300
100 MHz	Geology, Environmental	60 (20)	300-500

Antennas by Application

Radar is also not a continuous measurement along a survey line. The system takes readings (scans)at a set spacing. If your scan spacing is too wide, you risk not hitting your target with enough scans to draw a recognizable hyperbola, or worse, missing the target altogether. A good rule of thumb is to set your scan spacing so that you hit your target with at least 5-6 scans. For example, if you are looking for a 6 inch water pipe, you want your scan spacing to be at least 12/foot or 1/inch, but probably more like 18/foot. That way you will have 6 scans over the target and will have a better chance to see it.

Lower frequency antennas, like the 200 MHz and 400 MHz, will sometimes not image targets close to the surface very well. While not strictly a 'dead zone' you should be aware that it may be difficult (but not impossible!) to see targets in this area. As a general rule of thumb, this zone is equal to the spacing between the transmitter and receiver dipoles, but this can vary with soil composition. See the chart at right for a general idea. If your application requires you to see deep and shallow, consider surveying the area with two different antennas.

Frequency	"Hazy" Zone inches (cm)
1.5 GHz	1 (2.5)
900 MHz	4 (10)
400 MHz	6 (15.25)
200 MHz	12 (30.5)

Target Composition

Your ability to see a target depends on the contrast between the dielectric values of the target's material and the material that the radar energy was traveling through just before it hit the target. The greater the contrast between the dielectric values, the more visible the target is. For applications which involve finding metal targets like rebar, pipes, and drums, this is not a great issue because there will always be a great contrast. The dielectric of metals is so high that the actual number is meaningless. You will always have a visible contrast where metals are concerned.

Composition can affect your ability to see things in different ways. For example, the contact between a dry sand (3-6) and a water table (water being 81) will be easy to image, while the contact between sandstone (6) and limestone (7-8) will be much more difficult. Also remember that it is the electrical property of the material that most governs dielectric. Even though concrete and grade are qualitatively very different, they are made of similar materials and react to radar energy similarly. It is usually extremely difficult to tell the top of grade from the bottom of the slab. You should practice trying to image different materials so that you can build up a body of experience. See Appendix D for a chart of the dielectric constants of different materials.

B.3: Data Collection Methods: 2D vs. 3D

Time is money. Whether you are a university-based researcher working off a grant or performing NDT work for pay, the faster you can get the survey done the better off you will be. Those charging by the hour understand the fine balance between a price that reflects a realistic estimate of how long it will take to get the job done, and padding the cost with unnecessary work. The point of this discussion is to get you to think about how much information you really need to make a decision.

2D

Two-dimensional data collection means that you will be collecting and interpreting single profiles of data. This is useful for quickly following a pipe by scanning over an area, noting the location of the pipe hyperbola on the ground, then moving some distance away and scanning again for the pipe. The real benefit of 2D data collection is speed and ease of use. Processing is certainly possible on 2D data to clean up the image, but most clients will only use it for visually noting the presence/absence of targets in the field. 2D data collection is also useful for geologic applications such as bedrock and water table mapping.

3D

Collecting data for 3D imaging obviously takes more time than 2D collection. While the SIR-3000 makes it faster and easier than it has ever been before, it can still add significant time (and cost) to a job. It also requires some software processing to produce an interpretable image. These two issues may frighten some users away from 3D data collection, but like GPR in general, it only requires some practice to gain confidence.

Three-dimensional data can be a great aid in interpretation. The question many people ask is "When do I use 3D?" Aside from producing a 3D map for its own sake, there are really only three main reasons: a complicated area, prospecting, or dangerous targets in the subsurface. A complicated area might be a city street with many different types of pipes running in different directions. In a situation like that, the best option is usually to do 3D data collection so that you are able to visually track targets as they twist and turn around other targets. Prospecting is mainly what those doing Archaeology will face. In this case, you don't have any concrete information about the subsurface so you will need to do 3D over the area and look for human-made patterns that could be targets. An example of the final reason would be coring or cutting into an area that has live high-voltage in the floor. When the safety of your crew is at stake, the more information, the better.

Appendix C: Mounting Your SIR-3000 on a Cart.

Mobilizing your system on the GSSI Model 623 survey cart allows you to cover ground much more easily and conveniently than with the conventional system configuration described in Part 2.1. The cart can accommodate the 400 MHz, 900 MHz, and 1.5 GHz antennas. It also incorporates a survey wheel for high-precision distance measurements.

Step 1: Unfolding the cart and attaching the wheels.

Step 2: Mounting the antenna.

Step 3: Attaching the SIR-3000.

Step 4: Optional mounting of the 400MHz on the front of the cart.

C.1: Step 1: Unfolding the cart and attaching the wheels

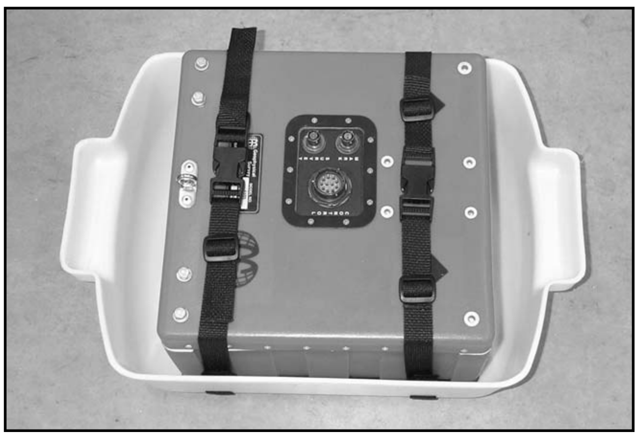
Unfold the cart frame and insert the black tips of the top assembly into the receivers on the front wheel fork. Secure with the attached pin.

Squeeze the silver wheel-lock clamps, and insert the wheel shaft into the axle. It will slide all the way in and lock securely. To remove wheels, squeeze the wheel-lock clamp again and pull the wheel straight out. Note: The wheels are foam filled and do not require inflation.

Slide the front wheel onto the front wheel fork and tighten clamp. When the clamp is slightly tight, turn the handle to the locked position (shown). This will further tighten the clamp. Exercise care not to over-tighten the front wheel as this may result in damage to the front fork.

Ensure that the survey wheel encoder is correctly positioned on the inside of rear left wheel and that the survey wheel is making contact with the tire's rim.

C.2: Step 2: Mounting the Antenna

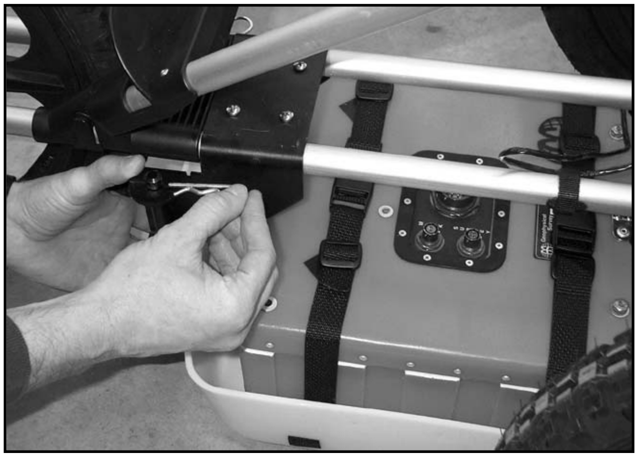


Place the antenna into the white plastic tub and secure with the attached straps. If you are using the cart system with the 1.5 GHz (Mod 5100) antennas, place the antenna in the tub, and then sandwich it between the bottom of the tub and the white plastic Velcro plate. Fix the straps over the top of the plate to secure.

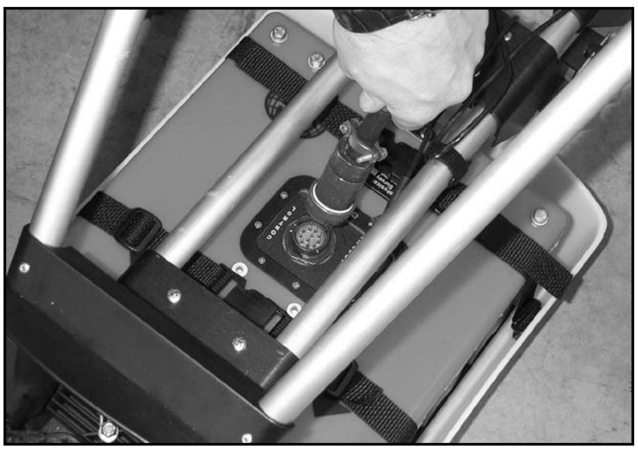
With the arrows on the top of the antenna housing pointing toward the front of the cart, place the tub under the cart so that the tub handles face the front and the back of the cart.

Lift the tub to fit the metal brackets under the handle and insert them through the 2 double holes on the frame.

Secure with the metal pins.



The antenna tub should just touch the ground surface. It is intended to be loose because it needs to be able to float over small obstacles. If you are using a small, higher frequency antenna, be sure that the antenna is centered in the tub.



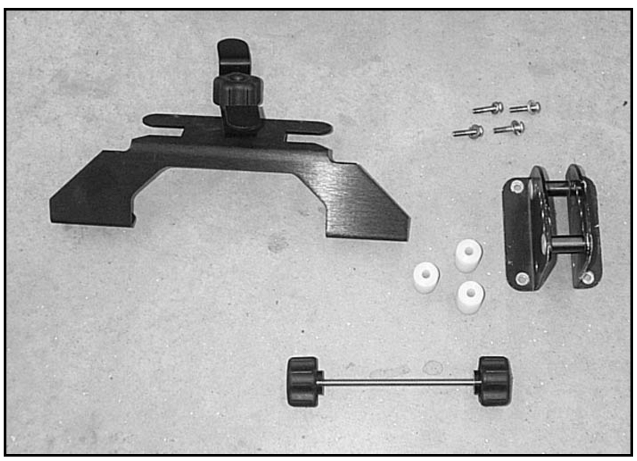
Connect the female end of the control cable to port that is labeled CONTROL and connect the lead from the survey wheel (4 pin) to the SURVEY port. These leads should only be hand tightened.

C.3: Step 3: Attaching the SIR-3000

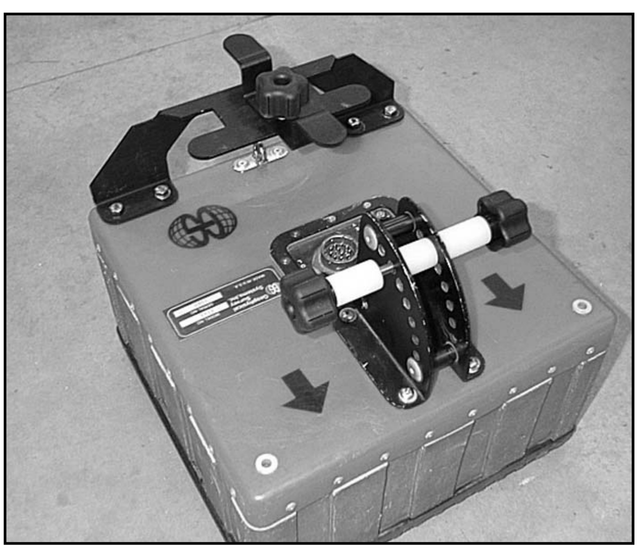
Hold the SIR-3000 in the mounting bracket so that all of the holes line up. Beginning with the top 2 holes, attach the SIR-3000 with the thumb screws. Pivot the SIR-3000 back and forth to get the most comfortable viewing position, and screw in the bottom 2 thumb screws. Be sure to only hand-tighten the screws. If you purchased the optional sunshade, be sure that it is positioned on the outside of the bracket rather than being sandwiched between the mounting bracket and the SIR-3000.

Attach the male end of the control cable to the antenna port on the back of the SIR-3000. Be sure to only hand-tighten this connection as over tightening may cause system damage.

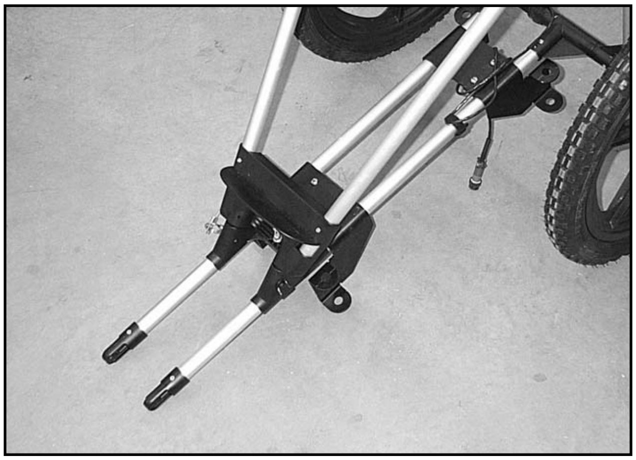
Step 4: Optional Mounting of the 400 MHz on the Front of the Cart.



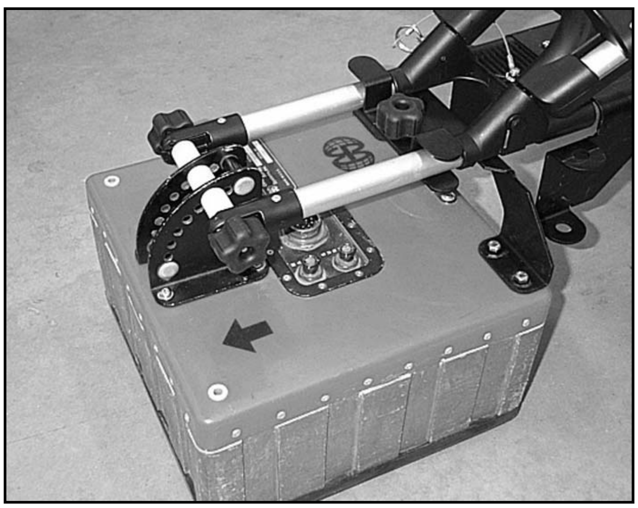
Collect the front mount kit parts.



Attach the kit to the 400 MHz antenna as shown.



Remove the front wheel from the cart by loosening the front axel release.



Attach the front fork of the cart to the antenna as shown. Tighten down the clamp at the rear of the antenna. All screws should be lightly snugged down.

Completed mount. This configuration allows you to scan much closer to a curbside or building.

Appendix D: Dielectric Values For Common Materials And Glossary Of Terms

Material	Dielectric	Velocity (mm/ns)
Air	1	300
Water (fresh)	81	33
Water (sea)	81	33
Polar snow	1.4 – 3	194 - 252
Polar ice	3 - 3.15	168
Temperate ice	3.2	167
Pure ice	3.2	167
Freshwater lake ice	4	150
Sea ice	2.5 – 8	78 – 157
Permafrost	1 – 8	106 – 300
Coastal sand (dry)	10	95
Sand (dry)	3 – 6	120 - 170
Sand (wet)	25 – 30	55 – 60
Silt (wet)	10	95
Clay (wet)	8 – 15	86 – 110
Clay soil (dry)	3	173
Marsh	12	86
Agricultural land	15	77
Pastoral land	13	83
"Average soil"	16	75
Granite	5 – 8	106 – 120
Limestone	7 – 9	100 – 113
Dolomite	6.8 – 8	106 – 115
Basalt (wet)	8	106
Shale (wet)	7	113
Sandstone (wet)	6	112
Coal	4 – 5	134 – 150
Quartz	4.3	145
Concrete	5 – 8	55 – 120
Asphalt	3 – 5	134 – 173
PVC	3	173

**Meter to English conversion factor: 2.54 cm in 1 inch.

** Table of Dielectric values adapted from:

Reynolds, John M.
1997 *An Introduction to Applied and Environmental Geophysics,* John Wiley & Sones, New York.

Appendix E: Listing of Antenna Parameters

The SIR-3000 comes with preloaded setups to fit the system's data collection parameters and filters to the most commonly used, currently available GSSI antennas. Settings for additional antennae are also provided below to assist you in creating a setup for an older or specialized antenna. Please note that these are only generalized setups, and it may be necessary to alter these to your particular situation. For example, deeper penetration can be set by increasing the range in the Collect > Scan menu.

E.1: Preloaded Setups:

1.5 GHz (Model 5100)

1.5 GHz ground coupled antenna. Depth of viewing window is approximately 18 inches in concrete. Setting is optimized for scanning of structural features in concrete.

Range: 12 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 2
Vertical High Pass Filter: 250 MHz
Vertical Low Pass Filter: 3000 MHz
Scans per second: 100
Vertical IIR High Pass N=2F=10 MHz
Transmit Rate: 100 KHz

900 MHz (Model 3101D)

900 MHz ground coupled antenna. Depth of viewing window is approximately 1 m assuming a dielectric constant of 5.

Range: 15 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 2
Vertical High Pass Filter: 225 MHz
Vertical Low Pass Filter: 2500 MHz
Scans per second: 64
Horizontal IIR Stack TC (Smoothing): 3 scans
Transmit Rate: 100 KHz

500-MHz

500 MHz antenna.

Data Collection Mode: Continuous
Range: 60ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 1000 MHz
Scans per second: 32
Horizontal Smoothing: 4 scans
Transmit Rate: 100 KHz

400 MHz (Model 5103)

400 MHz ground coupled antenna. Depth of viewing window is approximately 4m assuming a dielectric constant of 5.

Range: 50 ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 100 MHz
Vertical Low Pass Filter: 800 MHz
Scans per second: 64
Transmit Rate: 100 KHz

200 MHz (Model 5106)

200 MHz ground coupled antenna. Lower frequency antenna optimized for mid-range profiling.

Range: 100ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 50 MHz
Vertical Low Pass Filter: 600 MHz
Scans per second: 64
Transmit Rate: 100 KHz

100 MHz (Model 3207F)

100 MHz ground coupled antenna. Low frequency for deeper profiling.

Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 300 MHz
Scans per second: 16
Transmit Rate: 50 KHz

E.2: Parameter Listing for Older/Specialty Antennae

The following list of antenna setups is provided to assist you in using the SIR 3000 with additional antennae. To use this list, you must enter the correct parameters. You may wish to save any special parameters in a separate setup (under the System menu) to help you easily recall them. Some of these are no longer commercially available, but the system does function with all older antennas. They are designated by their center frequency, and in some cases a D or S which noted whether that setup is for Deep or Shallow prospecting. Please note that many of these antennae have a different listed transmit rate than the default one on the SIR 3000. The transmit rate listed here is the rate that the antenna was tested and rated at. It may function correctly at a higher transmit rate and allow you to collect data faster, but you must pay careful attention to your data to decide if the antenna is functioning correctly at the different rate.

If your system is beeping, it indicates that your T_RATE is too high for this antenna.

300-Deep

300 MHz antenna.

Data Collection Mode: Continuous
Range: 300ns
Samples per Scan: 1024
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 1000 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50 KHz

300-Shallow

300 MHz antenna.

Data Collection Mode: Continuous
Range: 150ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 1000 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50 KHz

120-Deep-Unshielded

120 MHz standard antenna.

Data Collection Mode: Continuous
Range: 400ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 240 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50 KHz

120-Shallow-Unshielded

120 MHz standard antenna.

Data Collection Mode: Continuous
Range: 200ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 240 MHz
Scans per second: 32
Horizontal Smoothing: 5 scans
Transmit Rate: 50KHz

100 High Power

100 MHz antenna with high power transmitter.

Data Collection Mode: Continuous
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 200 MHz
Scans per second: 16
Horizontal Smoothing: 5 scans
Transmit Rate: 12 KHz

100 Very High Power

100 MHz antenna with very high power transmitter.

Data Collection Mode: *Continuous*
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 200 MHz
Scans per second: 16
Horizontal Smoothing: 5 scans
Transmit Rate: 6 KHz

SubEcho 70

70 MHz antenna with high power transmitter.

Data Collection Mode: Continuous
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 15 MHz
Vertical Low Pass Filter: 150 MHz
Scans per second: 16
Horizontal Smoothing: 5 scans
Transmit Rate: 12 KHz

SubEcho 40

Data Collection Mode: Continuous
Range: 1000ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 10 MHz
Vertical Low Pass Filter: 80 MHz
Scans per second: 32
Transmit Rate: 12KHz

80 MHz

80 MHz folded bow-tie antenna. Note: The 80 MHz antenna is unshielded.

Data Collection Mode: Continuous
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 25 MHz
Vertical Low Pass Filter: 200 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 50 KHz

MLF 120 cm

Low Frequency antenna 1.2m length. Note: The MLF antennas are unshielded.

Data Collection Mode: Point
Range: 250ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 160 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

MLF 240 cm

Low Frequency antenna length 2.4m

Data Collection Mode: Point
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 15 MHz
Vertical Low Pass Filter: 90 MHz
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

MLF 360 cm

Low Frequency antenna length 3.6m

Data Collection Mode: Point
Range: 750ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 10
Vertical Low Pass Filter: 60
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

MLF 480 cm

Low Frequency antenna set to a length of 4.8m

Data Collection Mode: Point
Range: 1000ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 6
Vertical Low Pass Filter: 40
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12KHz

MLF 600 cm

Low Frequency antenna set to a length of 6.0m

Data Collection Mode: Point
Range: 1000ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 1
Vertical Low Pass Filter: 50
Scans per second: 32
Stacking: 32 scans
Transmit Rate: 12 KHz

Borehole 120 MHz

Borehole antenna frequency 120 MHz.
Note: The borehole antennas are unshielded.

Data Collection Mode: Point
Range: 500ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 30 MHz
Vertical Low Pass Filter: 240 MHz
Scans per second: 32
Stacking: 32 scans

Transmit Rate: 64 KHz

Borehole 300 MHz

Borehole antenna frequency 300 MHz.

Data Collection Mode: Point
Range: 300ns
Samples per Scan: 512
Resolution: 16 bits
Number of gain points: 5
Vertical High Pass Filter: 38 MHz
Vertical Low Pass Filter: 600 MHz
Scans per second: 32
Stacking: 32 scans

Transmit Rate: 50 KHz

Appendix F: Glossary of Terms and Suggestions for Further Reading.

Antenna: a paired transmitter and receiver that sends electromagnetic energy into a material and receives any reflections of that energy from materials in the ground. Also called a transducer. Antennae are commonly referred to by their center frequency value (i.e. 400MHz, 1.5Ghz). This frequency determines the depth of penetration and the size of the objects or layers visible.

Attenuation: the weakening of a radar pulse as it travels through different materials.

Center Frequency: the median transmit frequency of an antenna. The antenna will also transmit energy at a frequency range of 0.5-2 times its center value. For example, a 400 MHz antenna may actually transmit at a range from 200-800 MHz.

Clipping: occurs when the amplitude of a reflection is greater than the maximum recordable value. The system disregards the true value of the reflection and writes in the maximum allowable value. Clipping appears in the O-Scope as signal that "goes off the scale" at the sides of the window.

Dielectric permittivity: the capacity of a material to hold and pass an electromagnetic charge. Varies with a material's composition, moisture, physical properties, porosity, and temperature. Used to calculate depth in GPR work.

Gain: artificially adding signal to certain section of a radar pulse in order to counteract the effects of attenuation and make features more visible.

Ground-coupling: the initial entry of a radar pulse into the ground.

Hyperbola: an inverted "U." The image produced in a vertical linescan profile as the antenna is moved over a discrete target. The top of the target is at the peak of the first positive wavelet.

Interface: the surface separating materials with differing dielectric constants or conductivity values.

Linescan: commonly used method of depicting a radar profile. Linescans are produced by placing adjacent scans next to each other and assigning a color scheme to their amplitude values.

Macro: a preset list of processing options that may be applied to perform repetitive functions on an entire dataset. Macros may be created and edited to include different functions (see RADAN manual for addition information).

Mark: point inserted along a survey line manually by the operator or at preset intervals.

Migration: mathematical calculation used to remove outlying tails of a hyperbola and to accurately fix the position of a target.

Nano-second: unit of measurement for recording the time delay between transmission of a radar pulse and reception of that pulse's reflections. Equal to one one-billionth of a second.

Noise: unwanted background interference that can obscure true data.

Noise floor: time depth at which the noise makes target identification impossible.

Oscilloscope: device used to view and measure the strength and shape of energy waves. Common term in GPR industry for a method of data display showing actual radar wave anatomy.

Passband: the frequency range at which the antenna is emitting energy. It is roughly equivalent to 0.5-2 times the center frequency.

Range: the total length of time (in nanoseconds) for which the control unit will record reflections. Note: indicates two-way travel time.

Sample: a radar data point with two attributes: time and reflection amplitude. A third attribute, position, is assigned by the user. Under-sampling will produce a scan wave that does not contain enough information to draw a smooth curve. It may miss features. Over-sampling will produce a larger data file.

Samples/Scan: the number of samples recorded from an individual radar scan. Commonly set to 512.

Scan: one complete reflected wave from transmission to reception, sometimes called a trace.

Survey wheel: wheel attached to an antenna and calibrated to record precise distances. Necessary for accurate data collection.

Time-slice: a horizontal planview of amplitude values drawn from adjacent vertical profiles. The time-slice is produced for a particular time-depth and is vital for understanding the horizontal positions of features in a survey area.

Time window: the amount of time, in nano-seconds, that the control unit will count reflections from a particular pulse. Set by the operator.

Transect: a line of survey data. An area is systematically surveyed by recording transects of data at a constant interval. The transects are then placed in their correct position relative to each other in a computer and a horizontal time-slice is produced.

Wiggle trace: method of GPR data display showing oscilloscope trace scans placed next to each other to form a profile view. Commonly used method in seismic studies.

Further Reading

Annan, A.P., Cosway, S.W.
Ground-penetrating radar survey design. Paper prepared for Annual Meeting of SAGEEP.

Davis, J.L., Annan, A.P.
Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. Geophysical Prospecting 37, 531–551.

Conyers, Lawrence B., and Dean Goodman
Ground Penetrating Radar: An Introduction for Archaeologists. Altamira Press.

Hatton, L., Worthington, M.H., and Makin, J.
1986 Seismic Data Processing Theory and Practice, Blackwell Scientific Publications, Boston, MA., 177p.

Jackson, J.D.
1975 *Classical Electrodynamics.* Wiley & Sons.

Jordan, E.C., Balmain, K.G.
1968 *Electromagnetic Waves and Radiating Systems.* Prentice-Hall, NJ, pp. 139–144.

Oppenheim, Willsky and Young
1983 *Signal and Systems*. Prentice Hall.

Reynolds, John M.
1997 *An Introduction to Applied and Environmental Geophysics.* Wiley and Sons.

Roberts, R.L., Daniels, J.J.
1996 Analysis of GPR Polarization Phenomena. JEEG 1 2 , 139–157.

Sheriff, R.E., and Geldart, L.P.
1985 Exploration Seismology Volume 1 - History, Theory, and Data Acquisition, Cambridge University Press, New York, 253 p.

Sheriff, R.E., and Geldart, L.P.
1985 Exploration Seismology Volume 2 - Data-Processing and Interpretation, Cambridge University Press, New York, 221 p.

Telford, W.M., Geldart, L.P., Sheriff, R.E.
Applied Geophysics. Cambridge Univ. Press, MA, p. 291.

Wait, J.R.
Geo-Electromagnetism. Academic Press, New York.

Yilmaz, Oz
Seismic Data Analysis: Processing, Inversion, and Interpretation or Seismic Data. Investigations in Geophysics No. 10, Society of Exploration Geophysicists, Tulsa, OK.

Useful Websites:

1. Geophysical Survey Systems, Inc.:
   www.geophysical.com

2 American Database of Archaeological Geophysics:
   www.cast.uark.edu/nadag

3. United States Department of Agriculture Soils Website:
   http://soils.usda.gov/

4. USDA-Natural Resources Conservation Service, Ground Penetrating Radar Program:
   http://nesoil.com/gpr/

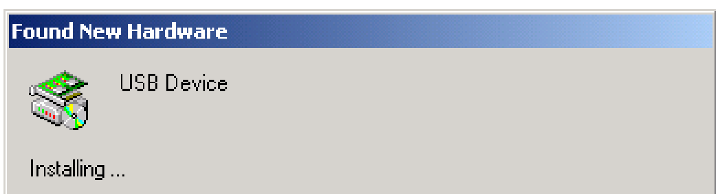
Appendix G: Installing Microsoft ActiveSync on Your PC

Connecting your SIR-3000 to your PC for the first time, and Installing Microsoft ActiveSync.

WARNING: RADAN 4.0.2.0 and 5.0.0.0 CDs have an older version of the SIR-3000 USB Transfer software that will significantly limit your transfer speed. If you had already installed the transfer software from one of these disks or from the previous version on the web site, please contact GSSI software technical support

Part 1: Having your PC recognize the SIR-3000 unit.

1. Please download the latest transfer software and instructions from http://www.geophysical.com/softwareupdates.htm. Navigate to the SIR-3000 software downloads. Download the SIR-3000 USB transfer software file "ASUSBwoMSASYNC.exe" and extract it to the root directory (typically C:\). Please note the location where you extracted it. You will need this information for a later step.
2. With both PC and SIR-3000 running, but not collecting or playing back data...
3. Plug Master (rectangular) end of USB cable into PC.
4. Plug Slave (square) end of USB cable into SIR-3000.
5. Your PC will generate a dialog stating that a new USB Device has been found.



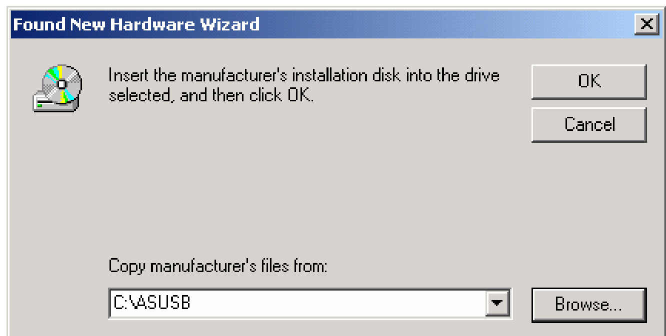
The remaining steps vary depending on operating system. Steps for both Windows 2000 and Windows XP are both included in two sections below:

Windows 2000:

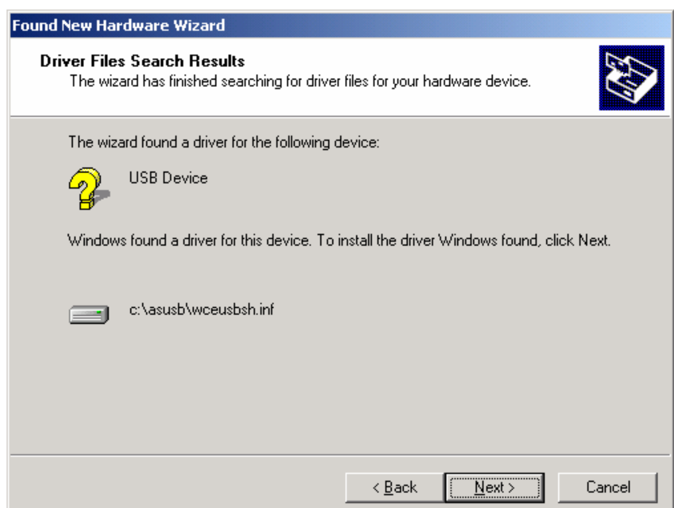
6. At the "Found New Hardware Wizard", click "Next>".
7. At the "Install Hardware Device Drivers" dialog, select "Search for a suitable driver for my device" and click "Next>".

8. At the Locate Driver Files dialog, deselect floppy and CD-ROM drives and select "Specify a location". Click "Next>".

8. When directed to "Insert the manufacturer's installation disk…", click "Browse". Find the directory you extracted the ASUSBwoMSAS drivers to earlier (either C:\ASUSB or C:\ASUSBwoMSAS directory by default) and select wceusbsh.inf. Click "OK".



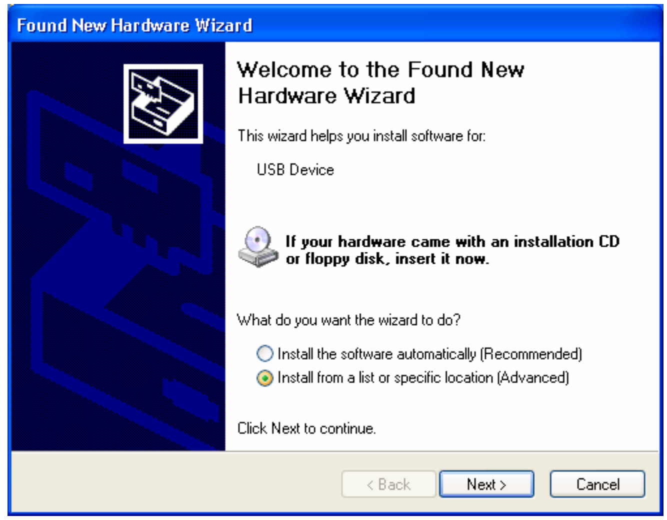
9. If you selected the correct directory, you get the following dialog. Click "Next>".



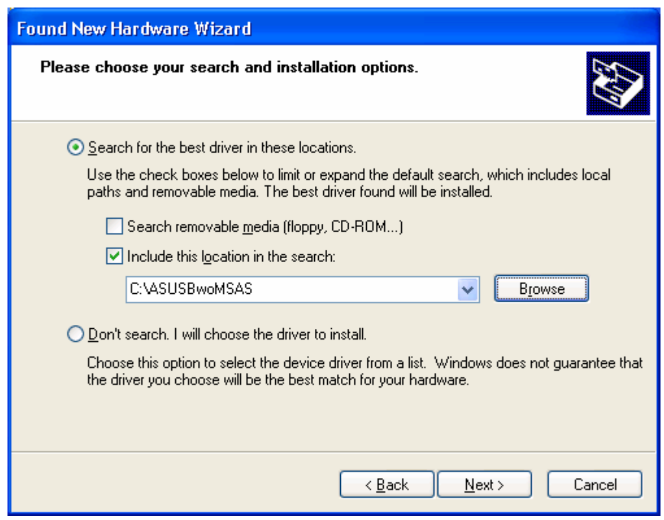
10. The installation is complete. Click "Finish".

Windows XP:

6. At the "Found New Hardware Wizard", select "Install from a list or specific location" and click "Next>".



7. At the "search and installation options" dialog, select "Search for the best driver in these locations" and "Include this location in the search". Click "Browse". Find the directory you extracted the ASUSBwoMSAS drivers to earlier (either C:\ASUSB or C:\ASUSBwoMSAS directory by default) and select wceusbsh.inf. Click "OK".

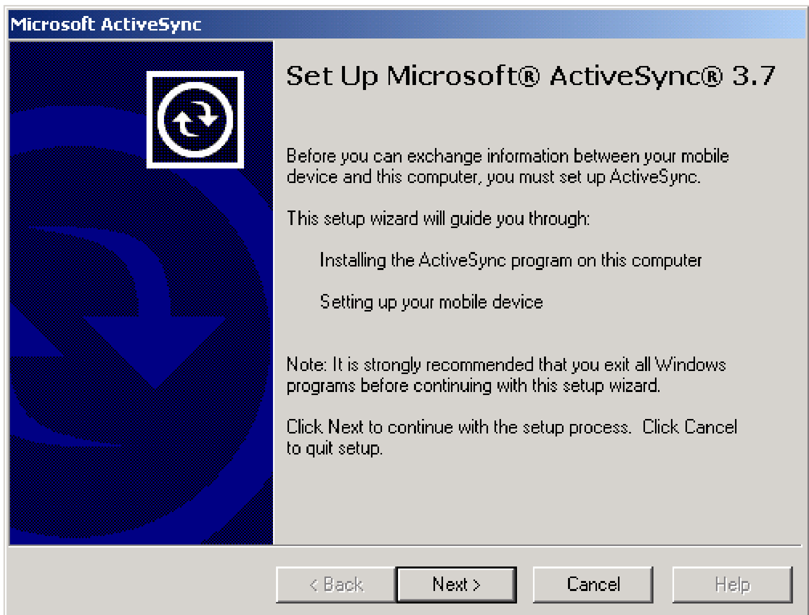


8. Finish the driver installation by following the onscreen instructions. You will see the following dialog. Select "Continue Anyway"

Part 2: Installing Microsoft ActiveSync

After the USB connection is installed, install the latest version of MS ActiveSync. It can be downloaded from Microsoft's web site.

1. Using a web browser go to http://www.microsoft.com/. Search for "Active Sync" or "ActiveSync".
2. Download the latest version of MS ActiveSync. If saved to disk, double click on the MSASYNC.exe icon directory to start the installation. It will copy files and then begin setup.

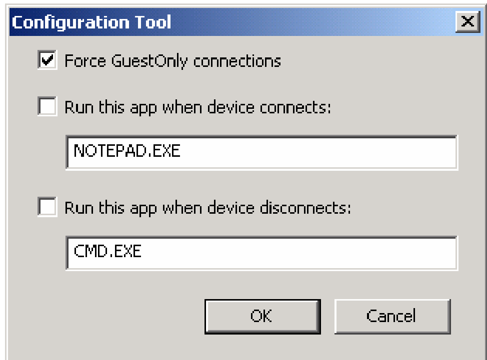


3. Follow the onscreen instructions to complete the Microsoft ActiveSync setup. Use the default folder if possible. It is likely that the installation will appear to hang at approx. 91% for a few minutes. Allow it to continue.
4. After completion you may see the "New Partnership" dialog. In order to successfully transfer SIR-3000 data via USB you will need to set up a guest connection with the SIR-3000. Select "No" at this dialog each time you connect your SIR-3000, as you do not synchronize any information with the PC. Synchronization is for Pocket PC users (and similar) who need to synchronize information. You should configure MS ActiveSync to bypass this dialog by following Step 1 of Part 3 below.

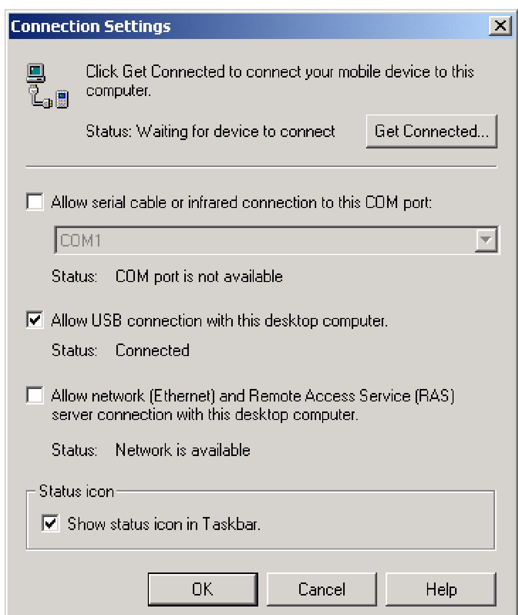
Part 3: Configuring Microsoft ActiveSync

If you have trouble with your MS ActiveSync connection to the SIR-3000 check your configuration.

1. If you do not want to respond to the "New Partnership" dialog each time you connect the SIR-3000 to your PC, find and double click on ActiveSyncKeys.exe in the ASUSB or ASUSBwoMSAS directory. Select "Force Guest Only connections", and click okay.



2. Double click on Microsoft ActiveSync icon. Go to File>Connection Settings... Make the selections shown below. Click "Next>".



3. At this point you should disconnect the USB cable from the SIR-3000 and reboot the SIR-3000. After the SIR-3000 starts reconnect the USB cable.
4. You should see the ActiveSync symbol turn green in the system tray at this point you can right click on that icon and select "Explore".
5. You can now Transfer data to your PC through the USB connection.